FM 6-40

INCLUDING C 1 and C 2

WAR DEPARTMENT FIELD MANUAL

FIELD ARTILLERY GUNNERY

THIS IS NOT A REVISION. This manual contains C1, 20 December 1945 and C2, 20 February 1947 to the 1 June 1945 edition placed at the back, following original texts, and will not be issued to individuals possessing that edition.

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WAR DEPARTMENT - 1 JUNE 1945

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This manual supersedes FM 6-40, 11 February 1942, including C1, 21 July 1942; C2, 7 July 1943; and C3, 16 December 1943, and WDTC 105, 1942

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WAR DEPARTMENT
Washington 25, D. C., 1 June 1945

FM 6–40, Field Artillery Gunnery, is published for the information and guidance of all concerned.

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BY ORDER OF THE SECRETARY OF WAR:

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For explanation of symbols, see FM 21–6.

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Paragraphs 79 to 169, inclusive, pages 44 to 150, inclusive, are superseded by Change 2, FM 6-40, 20 February 1947, which will be found at the back of this manual.

This manual supersedes FM 6–40, 11 February 1942; C1, 21 July 1942; C2, 7 July 1943; and C3, 16 December 1943, and WDTC 105, 1942.

PART ONE
GENERAL

CHAPTER 1
INTRODUCTION

1. GUNNERY. Gunnery is the practical handling of artillery fire. It consists generally of two phases: preparation of firing data and conduct of fire.

2. FUNDAMENTALS OF ARTILLERY FIRE.

a. The power of the artillery lies in the ability to concentrate effect from widely dispersed positions and to shift this effect from target to target.

b. The task of the artillery is to locate the enemy and destroy him by fire power, or to neutralize enemy action by the threat of destruction.

c. To be effective, artillery fire of *suitable density* must hit the target at the *right time* and with the *appropriate projectile* and *fuze.*

d. With good observation, effective fire can be placed on an enemy target. The search for targets and for probable locations of targets is most important. The observer must be skillful in the use of maps and photographs, and familiar with the methods and tactics of the enemy. Limited observation results in greater expenditure of ammunition and reduces the effectiveness of fire. Lack of observation must not preclude the delivery of fire.

3. SELECTION OF METHODS.

a. Gunnery methods are based on practical experience. Prescribed methods cannot cover all possible situations.

b. To overcome the adverse conditions of the battlefield, the artilleryman must possess initiative, good judgment, and a thorough knowledge of gunnery. He must be able to estimate situations promptly, to select appropriate methods of preparation of firing data and conduct of fire, and to estimate the number of rounds and quantity

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For military terms not defined in this manual see TM 20–205, and for list of Training Publications see FM 21–6.

of artillery which should be used. The artilleryman must continually keep in mind the location of friendly troops so that artillery fire may best support them.

4. ACCURACY. Field artillery doctrine demands delivery of fire by the most accurate means which time and the tactical situation permit. Inaccurate fire wastes ammunition and forfeits the confidence of the supported troops in the artillery.

5. TARGETS. Artillery is of no value to the supported arms without targets upon which to place fire. All intelligence agencies must be exploited to the utmost to determine the location or suspected location of targets for the artillery.

6. SCOPE. Battery gunnery is covered generally in PARTS ONE, TWO, and THREE. Battalion (and higher) gunnery is covered generally in PARTS THREE, FOUR, FIVE, and SIX. The text, however, should be studied as a whole, since no part can be entirely divorced from any other.

CHAPTER 2
ELEMENTARY BALLISTICS

7. GENERAL. The point of impact of a projectile for a given range is determined from the firing tables when all conditions of weather, ammunition, and weapon are standard. However, the projectile is acted upon inside and outside the tube by conditions nonstandard, with resultant dispersion and a different point of impact from that desired. An understanding of these factors and a reduction of their effects will increase accuracy.

8. INTERIOR BALLISTICS. Certain factors affect the projectile within the tube:

a. Wear of the tube, especially the forcing cone, is the normal result of firing; it is much greater when higher charges are fired than when low charges are fired. It is also increased by the firing of dirty ammunition and by improper care of the tube. A worn tube will permit an increase in the volume of the powder chamber by allowing the projectile to be rammed farther forward. It will also permit uneven seating of the projectile, which may allow gases to escape; and may also allow improper centering of the projectile, with resulting variations in muzzle velocity and instability in flight.

b. Cleanliness of the tube must be maintained to reduce erosion.

c. Hard, uniform ramming is necessary to obtain uniform seating of the projectile and hence more uniform muzzle velocity.

d. The rotating band must be smooth and free from burs and scars to permit uniform seating and to prevent the escape of gases.

e. Powder must be of uniform temperature and moisture content. Variations within lots and especially between lots will cause different rates of burning and variable muzzle velocity.

f. High charges will cause coppering in the tube, which will decrease the muzzle velocity of the first few rounds fired with a lower charge. The muzzle velocity returns to normal after several rounds have been fired at the lower charge.

g. Uniformity in density of loading must be obtained. A variation in the volume of the powder chamber or in the position of the charge

in the chamber changes the speed of burning, with resultant variation in velocity.

h. Variations in the weights of projectiles will cause variations in muzzle velocity.

i. Slight variations from standard in manufacture of the tube and variations in the adjustment of the recoil mechanism will cause *minor* differences in range.

9. EXTERIOR BALLISTICS. After the projectile has left the tube and before it reaches the point of impact, it is affected by many factors.

a. To keep an elongated projectile from tumbling during flight, it is given a rotating motion around its axis by the rifling of the tube. The action of air resistance, rotation, and gravity causes the projectile to deviate from the plane of fire, and this deviation is termed *drift.*

b. Weight of projectile. For the same muzzle velocity, a heavier projectile tends to travel farther than a lighter projectile of the same size and shape.

c. An increase in air density causes greater resistance and decreased range.

d. A variation in air temperature causes a variation in range.

e. Wind blows the projectile from the normal trajectory. A head wind decreases the range; a wind from the right blows the projectile to the left; the effect of an oblique wind is divided into components parallel and perpendicular to the direction of fire.

f. Muzzle velocity greater than normal will result in greater range.

g. When tilted to reach a target above or below the horizontal, the trajectory is altered by gravity (see par. 13).

h. The rotation of the earth affects the projectile in range and deflection, depending on the direction of fire.

i. The exterior surface of the projectile must be smooth. A rough surface on the projectile or fuze will increase air resistance, decreasing range and causing an error in deflection.

j. A heavy overcast increases air density and impedes the flight of the projectile, decreasing range. The effect of the impact of moisture particles against the projectile decreases its velocity.

10. CORRECTIONS. Since data in firing tables are based upon standard conditions which rarely exist, corrections for nonstandard conditions must be made. Factors in the firing tables will correct for the following known conditions: drift, variation of powder temperature, weight of projectile, air density, air temperature, differences in

muzzle velocity obtained from calibration and ammunition data cards, wind, and nonrigidity of the trajectory (complementary angle of site factors); and rotation of the earth tables for direction and range. Using personnel may correct or provide for the following factors: undue wear of the tube, by selection of the proper charge; cleanliness of the tube; uniform ramming; care of the rotating band; uniform powder temperature and powder lots; uniform placing of powder charges; segregation of projectiles by weight and exterior surface; and measuring the shooting strength of the gun by calibration. In spite of the application of these corrections and extreme care in the service of the piece, there are many factors which cannot be measured accurately. These will cause dispersion or variation in the point of impact from round to round under the same firing conditions. (Chap. 4, PART ONE.)

11. FORM OF THE TRAJECTORY.

a. In a vacuum. If there were no air to offer resistance to the projectile, the form of the trajectory would be determined entirely by the elevation, the muzzle velocity, and gravity (figs. 1 and 2). The form would be a symmetrical curve (approximately a parabola); the angle of fall would equal the angle of elevation, and the maximum ordinate would be at a point half way between the origin and the level point.

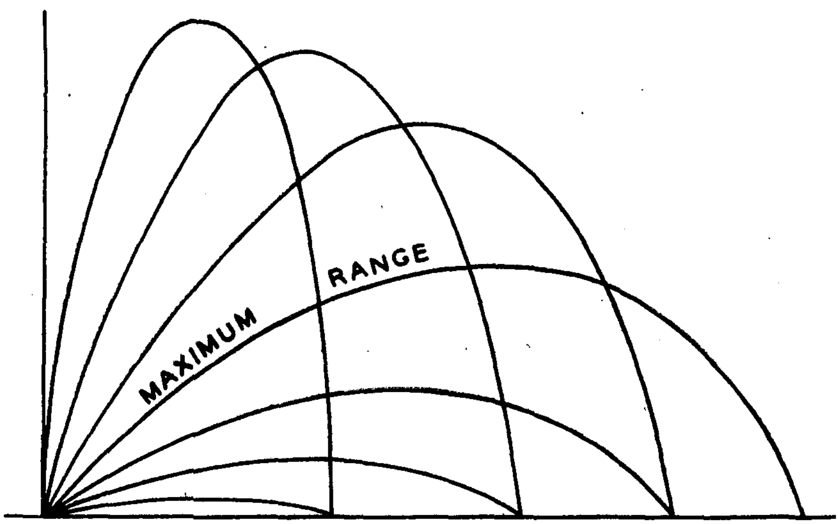


Figure 1. Variable elevation, constant muzzle velocity.

b. In the air. Resistance of the air retards the projectile from the instant it leaves the piece. This makes the trajectory a more complex curve than that in a vacuum; the angle of fall is greater than the angle of elevation, the maximum ordinate is closer to the level point than

Figure 2. Variable muzzle velocity, constant quadrant elevation.

to the origin, and the range is reduced. Air resistance is approximately proportional to the square of the velocity, and varies with the shape of the projectile. Retardation (the effect of air resistance on a projectile) depends upon the ratio of air resistance to mass of projectile. In general, retardation is less for large projectiles than for smaller ones of the same shape, because air resistance varies as the square of the caliber while mass varies as the cube.

12. ELEMENTS OF THE TRAJECTORY (fig. 3).

a. The *origin* is the center of the muzzle of the piece.

b. The *level point* is the point on the descending branch of the trajectory at the same altitude as the origin.

c. The *base* of the trajectory is the straight line joining the origin and the level point.

d. The *plane of fire* is the vertical plane containing the axis of the bore when the piece is fired.

e. The *line of fire* is the trace of the trajectory on a horizontal plane.

f. The *line of site* of a point is the straight line connecting the origin with that point.

g. The *plane of site* is the plane containing the line of site and a horizontal line perpendicular to it.

h. The *line of elevation* is the axis of the bore prolonged when the piece is laid.

i. The *angle of fall* is the angle between the base of the trajectory and the tangent to the trajectory at the level point.

j. The *angle of impact* is the angle between the tangent to the trajectory at the point of impact and the plane tangent to the surface of the ground at that point.

k. The *slope of fall* is the tangent of the angle of fall and is expressed as 1 on 10 (or so much).

l. Other elements of the trajectory are indicated in figure 3.

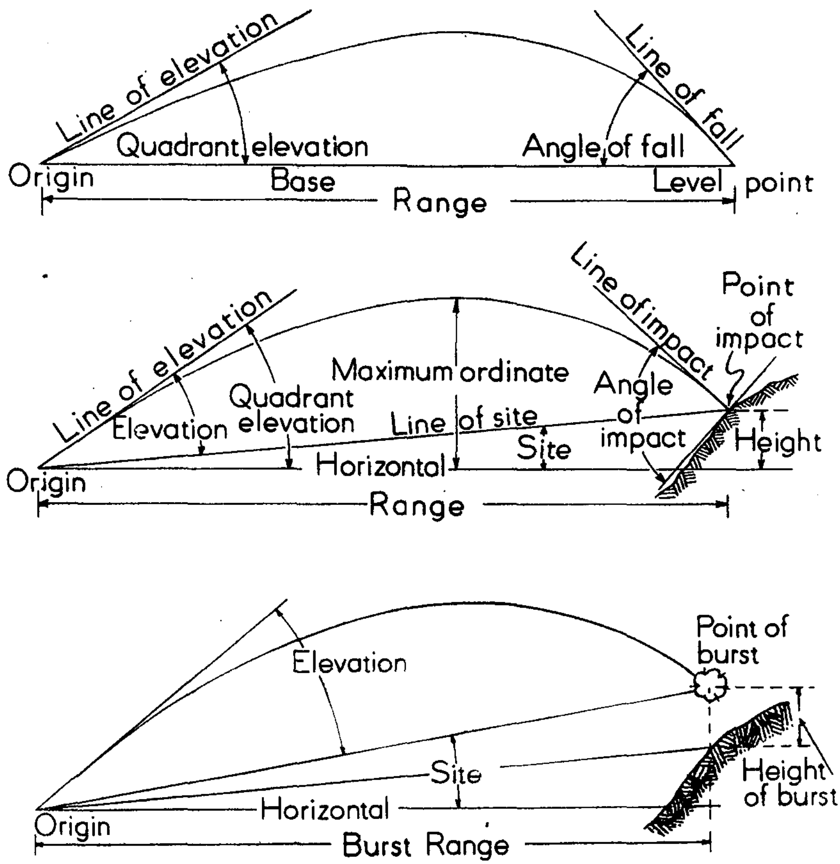


Figure 3. Elements of the trajectory.

13. RIGIDITY OF THE TRAJECTORY. The theory of the rigidity of the trajectory is the assumption that the trajectory may be tilted up or down through small vertical angles about the origin without materially affecting the shape of the trajectory. This assumption is utilized to obtain the quadrant elevation for a target above or below the piece by adding algebraically the angle of site of the target to the elevation necessary for range only. When large elevations are used with large angles of site, errors may be introduced by utilizing this assumption; therefore, in carefully prepared fire, elevation corrections should be determined from the complementary angle of site tables given in firing tables (accurate to angle of site of 25 mils or difference in altitude of 1000 feet, whichever is less).

CHAPTER 3
EFFECTS OF PROJECTILES; FUZE ACTION

14. PENETRATION IN SOIL. After a projectile strikes the ground and before it detonates, its path depends upon:

Angle of impact;
Shape, weight, velocity, and rotation of projectile;
Condition of surface of ground;
Composition and compactness of soil.

The resulting action is unpredictable except that certain general statements apply. These are:

a. Other conditions being equal, the amount of penetration varies with weight and striking velocity.

b. Increased compactness of the soil reduces the amount of penetration.

c. When the angle of impact is small (see par. 12j), the projectile tends to ricochet. When the angle of impact is moderately large, the projectile first penetrates and then tends to rise. If penetration is very great, the burst may produce a camouflet, that is, a hole underground,

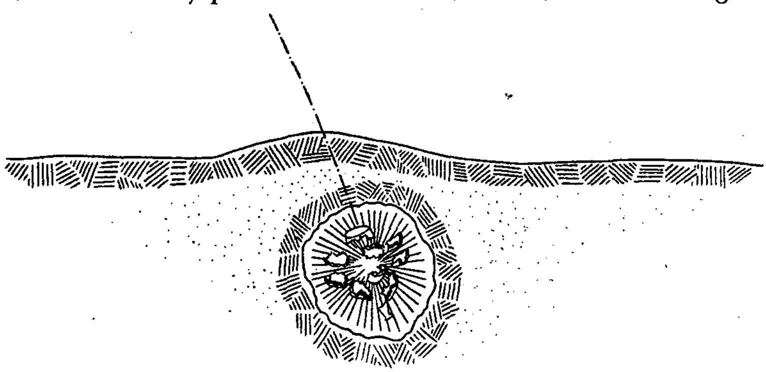


Figure 4. Effect of burst, deep penetration, steep slope of fall (cross section).

the surface of the ground remaining unbroken (see fig. 4). If penetration is moderately great, a crater is produced. Whether a camouflet or a crater is produced depends upon depth of burst, character of soil, and force of the detonation. When the angle of impact is large, the projectile continues downward until it stops or detonation occurs.

d. The rotation of the projectile, resistance of the soil, and inequalities of resistance may cause a projectile to turn from a straight path. The amount and direction of the deviation are unpredictable.

15. EFFECT ON CONCRETE. Observed effects on reinforced concrete of excellent quality are shown in the following table.

Weapon; Projectile (maximum charge)	Thickness of concrete perforated by single round (Face normal to angle of fall) (*feet*)			Number of rounds, falling in circle of given diameter*, necessary to perforate various thicknesses of concrete at given ranges									Remarks
				Range 1000			Range 2000			Range 3000			
	Range 500	Range 1000	Range 2000	Thickness (*feet*)			Thickness (*feet*)			Thickness (*feet*)			
				3	5	7	3	5	7	3	5	7	
57-mm AT gun; AP	2.7	2.6	2.1				Not available						Best to fire at ports and embrasures. Other employment is an expedient.
75-mm gun M3 (medium tank); HE M48, fuze M78	2.1	1.9	1.7	5	14	27	8	21	41	13	36	72	
3-inch gun (TD); HE M42B1, fuze M78	3.2	3.0	2.5	1–2	5	10	3	8	16	5	14	27	Effective weapon at short ranges.
90-mm gun; HE M71, fuze M78 or APC M82	4.0	3.8	3.4	1	3	7	1	5	10	3	8	14	Effective alternate weapon.
105-mm how M2-A1; HE M1, fuze M78	2.3	2.1	1.8	5	14	27	8	20	40	10	27	53	Effective against light concrete at short ranges.
4.5-inch gun M1; HE M65, fuze M78	4.7	4.6	4.1	1	1–2	5	1	3	8	1	4	10	
155-mm how M1; HE M107, fuze M78	4.0	3.9	3.5	1	3	7	1	4	9	1	5	11	
155-mm gun M1-17 (carriage M12); HE M101, fuze M78	5.5	5.2	4.9	1	1–2	3	1	2	4	1	2	5	Good weapon for perforating concrete.
155-mm gun M1; HE M107, fuze M78	6.8	6.6	6.1	1	1	2	1	1	2	1	1	3	Best results. Self-propelled weapon is desirable.
155-mm gun M1; AP M112	6.8	6.5	5.9	1	1	2	1	1	2	1	1	3	Best results. Self-propelled weapon is desirable.
8-inch how M1; HE M106, fuze M78	5.8	5.5	5.1	1	1	3	1	1–2	4	1	2	5	Excellent penetration and very accurate.
	Range 10,000	Range 12,000	Range 15,000	Range 10,000			Range 12,000			Range 15,000			
8-inch gun M1; HE M103, fuze M78			5.2	1	1	2	1	2	3	1	3	5	At shorter ranges (data not available) probability of perforation proportionately greater. Use should be an expedient.
	Range 8,000	Range 10,000	Range 12,500	Range 8,000			Range 10,000			Range 12,500			
240-mm how M1; HE M114, fuze M78			4.9	1	1	2	1	2	3	1	3	5	When 155-mm gun is not available. At these ranges. dispersion requires heavy expenditure of ammunition.

*Diameter of circles used as basis for data:

Caliber of weapon	*Diameter of circle*	*Caliber of weapon*	*Diameter of circle*
57-mm up to 3-inch	2½ feet	8-inch how and 8-inch gun	5 feet
90-mm to 4.5-inch	3 feet	240-mm how	6 feet
155-mm how to 155-mm gun M1	4 feet		

NOTES:

a. HE shell with quick or delay fuze, although not effective against concrete, is useful for exposing fortifications by blasting away camouflage and earth cover. With the anticoncrete fuze, HE shell is very effective. This fuze, nondelay, should be used for adjustment.

b. After a structure has been breached by AP projectiles, HE shell is effective in blowing apart the shattered concrete and in producing casualties.

c. HE-AT shell in all calibers (including 2.36-inch rocket) has only limited effect against concrete.

d. Fire into embrasures requires flat trajectories. Effectiveness of AP projectile depends upon high velocity. Firing at close ranges meets these conditions.

e. Thicknesses perforated are based upon a line of impact normal to surface. The effectiveness decreases rapidly when the line of impact is other than perpendicular to the surface. Ricochet will occur when the line of impact is 20 to 35 degrees and more from the normal. The higher the striking velocity, the greater this angle may be before ricochet occurs. After the surface has been chipped, this angle may be still greater.

16. EFFECT ON ARMOR (HOMOGENEOUS PLATE).

Weapon; Projectile	Thickness of armor perforated by single round (Angle of impact normal to surface of armor) (*inches*)		
	500-yard range	1000-yard range	1500-yard range
37-mm gun, M3A1, M6; APC-T, M51B1 or M51B2	2.9	2.6	2.2
57-mm AT gun, M1; APC-T, M86	4.0	3.5	3.1
75-mm gun, M3, M6; APC-TM, 61A1	3.3	3.0	2.7
75-mm how, M1, M1A1, M2, M3; HE-AT, M66	4 to 4.5	4 to 4.5	4 to 4.5
3-inch gun (TD), 76-mm gun, M1A1, M1A1C; APC-T, M62A1	4.7	4.3	3.9
105-mm how, M2A1, M3; HE-AT, M67	5 to 5.5	5 to 5.5	5 to 5.5
155-mm gun, M1918 (motor carriage M12); AP, M112 (2360 f/s)	6.9	6.7	6.5
155-mm gun M1; AP, M112 (2745 f/s)	7.6	7.5	7.2
2.36-inch rocket; HE-AT, M6A3	4		
76-mm gun, M1A2; APC-T, M62A1	4.7	4.4	4.1
76-mm gun, M1A1, M1A1C, M1A2, and 3-inch gun, M5, M7; HVAP-T, M93	8.4	7.3	6.2
90-mm gun, M1, M1A1, M2, M3; APC-T, M82 (2800 f/s)	6.4	6.0	5.6
90-mm gun, M1, M1A1, M2, M3; HVAP-T, T30E16 (3350 f/s)	11.2	10.0	9.0

17. EFFECT ON VEHICLES AND FORTIFICATIONS. Armor-piercing projectiles or shot and high explosive antitank shell are effective against armored vehicles and fortifications. Use of this ammunition is unprofitable against personnel or area targets because of its limited fragmentation.

18. EFFECT OF HE SHELL.

a. General. The action of the fuze and booster causes the bursting charge to detonate, driving fragments of metal forward (*nose spray*), transverse to the trajectory (*side spray*), and backward (*base spray*) (fig. 5). The side spray consists of a narrow zone of fragmentation. The nose spray and base spray each form a narrow cone. The initial velocity of fragments is on the order of 3000 feet per second. This initial velocity is combined with the terminal velocity of the projectile—the sum for nose spray, the difference for base spray, and the component for side spray. Incomplete detonation (*low order burst*) breaks the shell into a few large fragments.

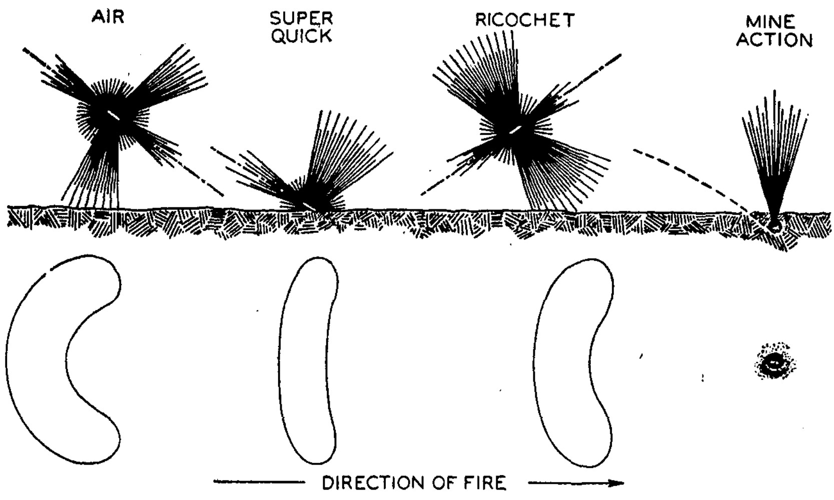


Figure 5. HE shell bursts.

b. Delay fuze.

(1) With delay fuze, the shell has time, before detonation, either to penetrate and produce mine action, or to ricochet. It is used for destruction missions which require penetration, and for ricochet fire.

(2) When penetration occurs and the shell is in earth at the instant of detonation, the fragmentation effect is zero. Penetration into a bunker or dugout will produce casualities by blast effect, suffocating gases, and fragmentation. Penetration into a masonry structure which has been shattered by AP projectiles will tend to blow the shattered

portions apart. Penetration into earth over a dugout may result in suffocating gases entering the dugout through fissures created by the detonation. Penetration into a structure built of logs, sand bags, or similar materials results in the blowing apart of constituent units; the effectiveness depends upon the amount of high explosive filler. The use of anticoncrete fuze increases the depth of penetration and the angle at which penetration may be obtained against reinforced concrete or heavy masonry targets.

(3) When ricochet bursts are obtained, the effect is similar to that of an air burst. Factors which determine whether a projectile will ricochet are:

Angle of impact;
Shape, weight, and velocity of projectile;
Length of delay of fuze;
Condition of surface of ground;
Composition and compactness of soil.

An increase in the angle of impact decreases the tendency to ricochet. It should be noted that many of these factors cannot be evaluated for the particular point of impact at the particular time of firing. Hence ricochet fire *must be observed,* and another type of fire used if a suitable percentage of ricochets cannot be obtained.

c. Quick fuze.

(1) With the quick fuze, projectiles burst either at the point of impact or when only a portion of the projectile has penetrated the ground. The impact must be on the nose of the present standard fuzes in order for the quick elements to operate. In these fuzes, the delay elements will act if the quick element is not activated. The fragmentation of the projectile is increased by increased angle of impact and by increased firmness of the ground. The effect is a function of the fragmentation and the density, size, and velocity of the fragments. When the projectile passes through foliage, the detonation may occur in the trees and effectiveness may be either improved or lost, depending upon the density of foliage. The quick fuze is suitable for use:

(*a*) In fire against personnel in the open when the angle of impact is large.

(*b*) In fire against personnel when neither ricochet nor time fire can be used.

(*c*) In fire against material objects, such as trucks, when penetration is not required.

(*d*) In firing chemical shell not provided with time fuze.

(2) The relative effectiveness of shell of the various calibers, with quick fuze, is indicated by the following table:

Caliber	Area Covered Effectively (*yards*)		Radius of Large Fragments (*yards*)
	Depth	Width	
75-mm	10	30	150
105-mm	15	50	300
4.5-inch (estimated)	16	55	
155-mm	18	60	550
8-inch	20	80	
240-mm (estimated)	25	100	

The area covered effectively is considered to be that area in which there is at least a 50 per cent chance that a man standing will become a casualty. The area is roughly elliptical.

(3) The wire cutting effectiveness of shell is poor. The employment of artillery fire to breach wire requires extravagant use of ammunition.

d. Time fuze.

(1) With time fuze, the point of burst is determined by the quadrant elevation, charge, and time setting (minor variations are caused by variations in velocity of projectile, density, and temperature of air, wind, etc.). Should impact occur before action of the time element, quick fuze action takes place (except with those types of time fuze not provided with an impact element).

(2) Factors which govern the effectiveness of air bursts against entrenched targets are:

Number, size, and velocity of fragments;
Height of burst above target;
Horizontal distance of burst from target;
Shape and size of trench;
Direction of fragments.

The direction of the fragments is governed by a combination of the angle of fall, striking velocity of the projectile, and the initial velocity of the fragments due to detonation. The side spray fragments are driven in a zone roughly 15 to 20 degrees in thickness, generally normal to the trajectory (see fig. 6). This direction is modified by the forward motion of the shell. The fragments which are driven more or less upward are ineffective. The fragments which are driven more or less laterally will be partially effective depending on final velocity, direction, and other factors. The fragments driven more or less downward will be the most effective.

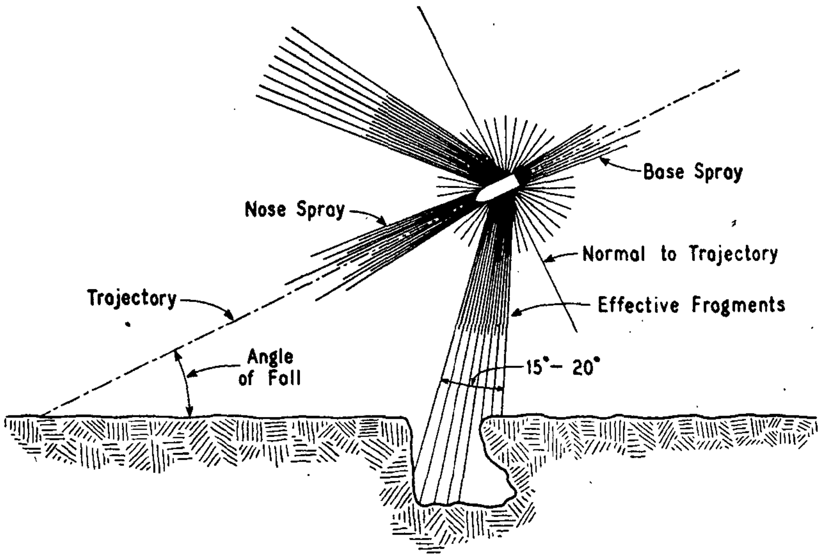


Figure 6. Effect of burst with time fuze.

(3) For each type of projectile there is a most effective height of burst. Because of dispersion, it is impossible to secure all bursts at that height. Some bursts will be lower and some will be higher than the mean height. For a given range, the probable error in height of burst is controlled by choice of charge. Range and charge have no direct influence on the effectiveness of time fire, but do have a marked indirect influence on the resulting height of burst probable error. Therefore, considering ineffective high air bursts and graze bursts, the most effective mean height of burst is 20 yards.

e. Effectiveness in clearing mine fields. HE shell is ineffective for clearing mine fields, regardless of the type of fuze employed. Mines are not sufficiently sensative to be detonated by shell bursts, except by direct hits. Artillery fire not only fails to eliminate the mine field, but increases the difficulty of locating and removing mines by hand, and increases the difficulty of moving across the field.

19. COMPARATIVE EFFECTIVENESS OF IMPACT, RICOCHET, AND TIME FIRE WITH HE SHELL.

a. Against personnel in the open, the order of effectiveness is: ricochet fire, time fire, high angle fire with quick fuze, low angle fire with quick fuze, and mine action (zero). This sequence may vary because of local conditions of soil, terrain, and vegetation. Time fire cannot be used beyond the range corresponding to the limiting time

of functioning of the fuze. When the percentage of ricochets is below 70, time fire is most effective.

b. Against personnel in shallow trenches, the effectiveness of various types of fire under ideal conditions is in the same sequence and is governed by the same conditions as in subparagraph a above. However, it should be noted that range dispersion to the point of burst in ricochet fire is considerably greater than it is in time fire (because of irregularities in contour of ground and variations in ricochet distance), and that for entry into trenches, the angle of approach of the fragments from ricochets is much less favorable than is that from time fire. The base spray, effective against personnel in the open, is too nearly parallel to the ground to enter fox holes. Impact fire is very ineffective against targets in trenches.

c. Against personnel in deep trenches, time fire is more effective than ricochet fire and outstandingly more effective than impact fire. However, under certain conditions of soil and cover, it may be necessary to utilize the penetration effect of delay fuze.

20. CHEMICAL SHELL.

a. Gas shell is filled with irritant or toxic agents. Action of the fuze and booster breaks open the shell. Liquid vesicants are most effective against personnel when sprayed directly and are very effective against personnel when sprayed on vegetation. Time, ricochet, or quick fuze action is far preferable to mine action. Many small projectiles are more effective than a few large ones for attack with liquid vesicants. With irritant gases and smoke, quick fuze action is preferable. Only medium and heavy artillery are capable of building up an effective concentration of these latter agents.

b. White phosphorus produces smoke, incendiary effect, and casualty effect. In all three roles, superquick fuze action is preferable. Below ground, the phosphorus only smoulders. With a burst at medium height in the air, the particles burn out before reaching the ground; the smoke rises because of heat produced in burning.

c. Base ejection type smoke shell with time fuze is more effective as a screening agent than is white phosphorus. On impact the effect is nearly zero. The action of the fuze and bursting charge ignites the smoke charges and forces them out of the base of the shell with a relative velocity of about 200 feet per second. The case continues along the trajectory, and the smoke charges follow with reduced velocity. They fall somewhat short of the case, the distance depending upon height of burst.

CHAPTER 4
DISPERSION

21. THE DISPERSION PATTERN. If several rounds were fired from a piece under conditions as nearly identical as possible, the points of impact of the projectiles would be dispersed about a point called the *center of impact* (fig. 7). The following are characteristics of the dispersion pattern:

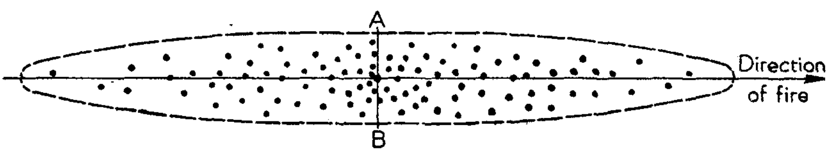


Figure 7. The dispersion pattern; the center of impact is the point at which line AB intersects the line of fire.

a. The pattern is roughly elliptical; its center is the center of impact, and its long axis lies along the line of fire.

b. Shots are scattered more in range than in deflection.

c. Shots are grouped more closely toward the center than toward the edges of the pattern.

d. If a sufficient number of rounds is fired, as many will fall beyond the center of impact as short of it, and as many to the right as to the left.

22. DISPERSION ERRORS.

a. *Dispersion errors* are errors inherent in the dispersion pattern (such as those caused by manufacturers' tolerances and those errors inherent in the piece and ammunition); they are the result of variations of certain elements, from round to round, even though conditions are as nearly identical as possible. Dispersion errors are generally beyond control, except that errors due to personnel can be reduced by careful laying and loading. Dispersion errors should not be confused with *mistakes* or *constant errors;* these are not inherent in the dispersion pattern. Mistakes can be eliminated by care and training; *constant errors* can be compensated for by appropriate corrections.

b. For practical purposes, the dispersion error of a shot is the distance from that shot to the center of impact; a dispersion error may be resolved into its range and deflection components.

23. RANGE PROBABLE ERROR.

a. In figure 8, AB is a line through the center of impact perpendicular to the line of fire. CD is drawn parallel to AB so that there are as many shots beyond CD as there are between AB and CD. The distance between these lines (depth of the 25 per cent zone) is the *range probable error,* because this error is exceeded as frequently as it is not exceeded. The value of the probable error is given in the firing tables and may be taken as an index of the accuracy of the piece.

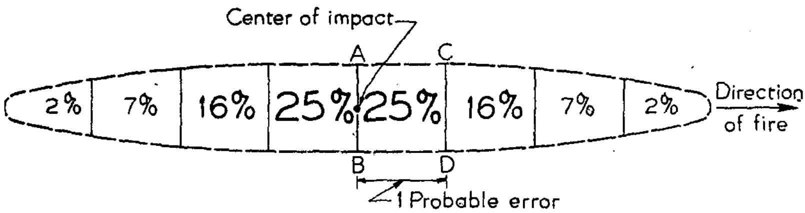


Figure 8. The dispersion diagram.

b. If lines are drawn parallel to AB at distances of one probable error the percentages of shots falling in each subdivision will be approximately as indicated in figure 8. Eight applications of this interval (four on each side of the center of impact) will include the dispersion pattern.

24. FORK. The fork is the change in elevation necessary to move the center of impact four probable errors. It is sometimes used as a unit of range (elevation) change in conduct of fire. Its value is given in the firing tables as a function of the elevation.

25. DIRECTION PROBABLE ERROR. In the dispersion diagram (fig. 8) if the long axis is considered instead of the line AB, the shots to the right and left of the axis follow rules of distribution similar to those given in paragraph 23. The direction probable error is one eighth the width of the dispersion pattern at its greatest width. This value is given in the firing tables.

26. VERTICAL PROBABLE ERROR. If fire is directed against a vertical plane, the dispersion in this plane follows the same laws as dispersion in a horizontal plane (fig. 9). The shots are all contained in a vertical dispersion pattern and the vertical probable error is one eighth the height of the pattern. The vertical probable error is the product of the range probable error and the slope of fall (tangent of

the angle of fall). Values for the range probable error and slope of fall are given in the firing tables.

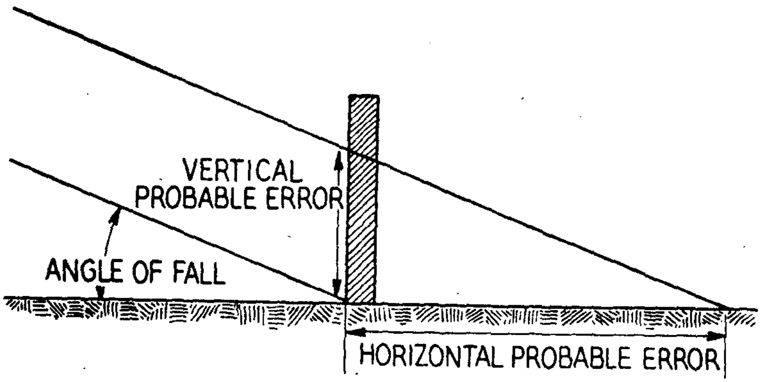


Figure 9. Relation of vertical probable error to horizontal probable error.

27. MISCELLANEOUS ERRORS. Dispersion on a horizontal plane may be projected on a forward or reverse slope by considering that slope and the angle of fall. In time fire, the projection of the bursts (for any particular time setting) on any plane will give the dispersion pattern in that plane.

28. APPLICATION OF DISPERSION.

a. Location of target with reference to the center of impact. Consider the pattern of six shots fired under identical conditions (fig. 10). Four of these (66 2/3 per cent) have been sensed short of a target and two of them over, the exact location of the target within the pattern being unknown. For a very large number of shots, 50 per cent can be expected to fall short of the line AB (range center), and 75 per cent short of the line CD (fig. 8); therefore (assuming linear interpolation to be correct), 66 2/3 per cent can be expected to fall short of the line MN, which is two thirds of the way from AB to CD. The line MN then represents the most probable location of the target. The rule of computation for precision fire is based on the foregoing principle.

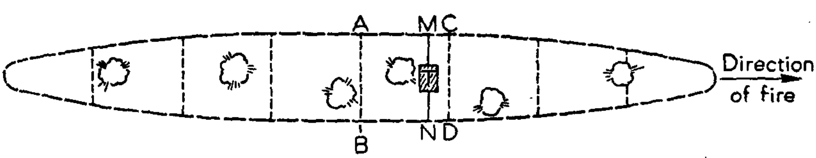


Figure 10. Determination of location of target by dispersion diagram.

b. Dispersion as seen by a lateral observer. To an observer conducting fire from a position off the gun-target line, the deviations caused by range dispersion are very apparent. It is often advantageous to know the deviations caused by normal dispersion. These can be computed quickly by using proportional parts of the value of *d* (par. 127a). Deviations corresponding to less than two range probable errors should be ignored and another round should be fired at the same elevation.

c. Probability of hitting an area. Considering that range and deflection errors are measured at right angles to each other, the dispersion pattern may, for purposes of computation, be considered as a rectangle (fig. 11). The distribution of shots throughout this rectangle can be obtained by applying the dispersion scale along both dimensions. The propability of hitting a certain area within the rectangle can then be quickly determined as the product of the probability of a hit for range and the probability of a hit for deflection; also, the expenditure of ammunition necessary to obtain a given number of hits in this area (the settings on the piece remaining unchanged) can be computed.

	.02	.07	.16	.25	.25	.16	.07	.02
.02	.0004	.0014	.0032	.0050	.0050	.0032	.0014	.0004
.07	.0014	.0049	.0112	.0175	.0175	.0112	.0049	.0014
.16	.0032	.0112	.0256	.0400	.0400	.0256	.0112	.0032
.25	.0050	.0175	.0400	.0625	.0625	.0400	.0175	.0050
.25	.0050	.0175	.0400	.0625	.0625	.0400	.0175	.0050
.16	.0032	.0112	.0256	.0400	.0400	.0256	.0112	.0032
.07	.0014	0049	.0112	.0175	.0175	.0112	.0049	.0014
.02	.0004	.0014	.0032	.0050	.0050	.0032	.0014	.0004

Figure 11. Rectangle of dispersion.

d. Application of dispersion scale in determing ammunition expenditures.

(1) The dispersion scale can be of use in determining the probability of hits on a target of fixed dimensions, with respect to which the position of the center of impact can be determined. This information is useful in estimating ammunition expenditures for destruction missions. The table below gives probable expenditures per target hit on a selected target for three weapons of different caliber. For each caliber the location of the center of impact was assumed, in one

case, to be at the target center, and in the other case to be two range probable errors (e_{pr}) over or short of the center of the target.

Target: bridge—10 yards wide, 40 yards long (range).

Range: 18,000 yards.

Charge: maximum charge.

Weapon	Range Probable Errors e_{pr}	Deflection Probable Errors e_{pd}	Location of CI	Probability of Obtaining One Hit for Round (%)			Rounds Required for One Hit
				Range	Df	Rn and Df	
155-mm gun M1	43	9	Target center	23.2	27.8	6.5	16
	43	9	2 e_{pr} (86 yds) over or short of target center	10.6	27.8	2.9	34
8-inch how M1	19	6	Target center	51.6	41.7	21.6	5
	19	6	2 e_{pr} (38 yds) over or short of target center	24.5	41.7	10.2	10
240-mm how M1	36	8	Target center	27.8	31.2	8.7	11
	36	8	2 e_{pr} (72 yds) over or short of target center	12.9	31.2	4.0	25

(2) The data above for the 8-inch howitzer, center of impact located at the target center, is computed as follows:

(*a*) First determine the probability of a hit for range only. The target is 40 yards or $40/19 = 2.1$ probable errors in length. Two probable errors of the length cover the 25 per cent zones of the range dispersion scale, the remaining 0.1 probable error falls in the 16 per cent zones.

$$\%\text{ range hits} = 0.05\,(16) + 1\,(25) + 1\,(25) + 0.05\,(16) = 51.6\%.$$

(*b*) In like manner, determine the probability of a hit for deflection only. The target is 10 yards or $10/6 = 1.67$ probable errors in width. The total width of the target falls in the 25 per cent zones of the deflection dispersion scale.

$$\%\text{ Df hits} = 0.83\,(25) + 0.83\,(25) = 41.7\%.$$

(*c*) The product of these two probabilities is the probability of a hit for both range and deflection.

$$\%\text{ hits} = .516 \times .417 = 21.6\%.$$

(*d*) The probable number of rounds per target hit is equal to the reciprocal of the probability of a hit.

Rounds required for one hit $= 1/.216 = 4.6$ or 5.

(3) Computations of data for the 240-mm howitzer M1, center of impact two range probable errors (e_{pr}) over or short, are made as follows:

(*a*) As in the preceding example, first determine the probability of a hit for range only. The distance from the center of impact to the far end of the target is $(2 \times 36) + 20 = 92$ yards or $92/36 = 2.56$ probable errors. One of the 2.56 probable errors covers the 25 per cent zone, one the 16 per cent zone, and the remaining 0.56 probable error falls in the 7 per cent range dispersion zone.

% range hits between center of impact and far limit of target = $1 (25) + 1 (16) + 0.56 (7) = 44.9\%$.

However, a distance of 52 yards (*i.e.* 72 minus 20) or $52/36 = 1.44$ probable errors of the above does not include the target, and probable hits in this space must be excluded.

% range hits between center of impact and near limit of target = $1 (25) + 0.44 (16) = 32.0\%$.

% range hits on target $= 44.9 - 32.0 = 12.9\%$.

(b) The target is 10 yards or $10/8 = 1.25$ probable errors wide. The total width of the target falls in the 25 per cent zones of the deflection dispersion scale.

% deflection hits $= 1.25 (25) = 31.2\%$.

(c) The product of these range and deflection probabilities is the probability of a hit for both range and deflection.

% hits $= .129 \times .312 = 4.0\%$.

(d) Rounds required for 1 hit $= 1/.040 = 25$.

e. Probabilities related to conduct of fire.

(1) PROBABILITY THAT TARGET IS WITHIN BRACKET.

Number of Sensings		Probability (%)		
At One Limit	At the Other	1-fork Bracket	2-fork Bracket	4-fork Bracket
1	1	70	85	92.3
1	2	75	89	96
1	3	76	90	97
2	2	85	94.5	99+
3	3	92.5	98	99+

(2) PROBABILITY THAT TARGET IS WITHIN ZONE OF DISPERSION OF CENTER OF 1-FORK RANGE BRACKET. A 1-fork bracket has been obtained with one sensing at each limit; the probability that the target is within the zone of dispersion of rounds fired at the center of the bracket is 96.8 per cent. This probability is increased as additional verifying sensings are obtained.

(3) PROBABILITY THAT CENTER OF IMPACT IS WITHIN A GIVEN DISTANCE OF THE TARGET WHEN BOTH SHORTS AND OVERS ARE OBTAINED WITH ONE ELEVATION SETTING.

Number of Sensings		Probability (%)			
		Distance in Probable Errors			
In One Sense	In the Other	One	Two	Three	Four
1	1	54	86	98	99+
1	2	51	86	98	99+
1	3	44	80	96	99+
2	2	70	96	99	99+
3	3	99+	99+	99+	99+

PART TWO
THE FIRING BATTERY

CHAPTER 1
INITIAL LAYING; COMMANDS AND REPORTS

29. GENERAL. FM 6–140 describes in detail the various duties, operations, and requirements pertaining to the firing battery. Only such material is included in PART TWO as is required to provide complete understanding of the part played by the firing battery in the effective delivery of fire.

30. INITIAL LAYING.

a. The executive lays the battery parallel initially and whenever he is ordered to record base deflection. (See also pars. 72 and 90b.)

b. When only a general direction of fire has been designated, the executive lays the battery in that direction on a definite *Y*-azimuth which is a multiple of 100.

c. At the earliest opportunity, the executive determines the *Y*-azimuth of the initial direction and the referred deflection to any visible aiming point. He has aiming posts set out and pieces referred. If he has laid the battery initially on an aiming point, he does not delay opening fire to have aiming posts set out.

d. An aiming point should be fixed, easily identifiable, with a clearly defined vertical line, and should be in a convenient direction. Other considerations being equal, the more distant aiming point is selected.

31. MAGNETIC METALS. When the needle of an aiming circle is used, the instrument is set up at the following minimum distances from objects which will affect the needle:

	Yards
High tension power lines	150
Railroad tracks	75
Heavy gun	60
Light gun; telegraph wires	40
Barbed wire	10

Steel helmets, small arms, eyeglasses, and other metallic objects which affect the needle are moved away during use of the needle.

32. MINIMUM ELEVATION.

a. As soon as the position is occupied, the battery executive determines the minimum elevation (FM 6–140) and reports the amount to the fire-direction center and battery commander. If this elevation is a decimal, it is reported to the next higher whole mil.

b. In case it is necessary to determine more than one mimimum elevation in the zone of fire, the executive reports, for example: "*Y*-azimuth 4850 to 5200, minimum elevation 55; 5200 to 5650, minimum elevation 42."

c. A single narrow obstruction, such as a tree, which will mask only one piece at a time, is not considered by the executive in computing minimum elevation. If a piece cannot fire safely, it is called *out.*

33. REPORTS BY THE EXECUTIVE.

a. As soon as the information is available and can be transmitted without interrupting fire, the executive reports to the battery commander and to the battalion fire-direction center:

(1) *Battery is ready.*

(2) *Minimum elevation (s) charge (so-and-so) (so much).*

(3) *Distribution of pieces (to nearest 5 yards): No. 1 (so many) yards right (left), so many yards behind (ahead of) No. 2; No. 3, etc.* The base line or indicated direction is used as an origin of direction. When time permits, this report should be submitted as a diagram.

(4) *Visible aiming points (so-and-so)* (not reported to fire-direction center).

b. When directed, the executive reports, in addition:

(1) Amount, type, lot, and weight of ammunition.

(2) Powder temperature.

(3) *Maximum shifts Y-azimuths (so much) to (so much) or BDR (so much) to BDL (so much).* These are the maximum shifts which can be made without necessitating the movement of the pieces to establish a new battery front, and within which at least three fourths of the pieces can deliver fire at and above minimum elevation.

(4) Maximum elevation (when high angle fire is to be used).

34. REPORTS BY OPERATOR.

a. At the first round or salvo, volley, zone, or other series of fire, the telephone (radio) operator reports to the officer conducting fire; for example, "On the way," or "4600 on the way," or "No. 1 on the

way," as may be appropriate. On completion of the fire commanded, he reports, "Rounds complete."

b. At the end of each mission, the operator reports to the officer conducting fire the number of rounds (obtained from the recorder) expended on the mission.

c. The operator reports immediately any attack which requires close defense of the battery position or protective measures for personnel.

35. REPORTING ERRORS IN FIRING. Chiefs of section must report immediately to the executive all errors that have caused a round to be fired with improper data. The executive has these errors corrected and reports them to the officer conducting fire; for example: "No. 2 fired 20 mils right; has been corrected."

36. CHECKS OF SETTINGS AND CHARGES DURING FIRING. The executive usually checks settings and layings during lulls in firing only. When in doubt about the accuracy of the laying of any piece, he calls that piece out, reports to the officer conducting fire, *"No. (so-and-so) out,"* and has the necessary checks made. When semifixed and separate loading ammunition are fired, unused charges are checked and disposed of as directed by the battery commander. The executive must at all times use ingenuity and initiative to see that the battery is laid promptly and that accurate fire is delivered when called for.

CHAPTER 2
FIRE COMMANDS AND THEIR EXECUTION

37. SEQUENCE.

a. Pieces to follow commands, special methods of adjustment, and particular missions.

b. Projectile.

c. Charge.

d. Fuze. (In time fire, after initial commands, the command for time immediately precedes the command for elevation.)

e. Direction.

f. Distribution.

g. Site.

h. Pieces to fire.

i. Method of fire.

j. Use of quadrant or elevation scale.

k. Elevation or range.

38. ORIGIN AND TRANSMISSION. Fire commands may originate with the observer, the computer at the fire-direction center, or the computer at the battery. They are sent to the executive by the best available means of signal communication. The executive, or operator if directed, repeats to the howitzer (gun) sections all commands received, except as specifically noted in this manual.

39. NUMBERS. Numbers are announced as illustrated in the following examples:

10–One zero.
25–Two five.
300–Three hundred.
1400–One four hundred.
6000–Six thousand.
3925—Three nine two five.
4050—Four zero five zero.
10,000—One zero thousand.
10,300—One zero three hundred.
11,000—One one thousand.
100.7—One zero zero point seven.
254.4—Two five four point four.

40. OPENING FIRE.

a. The command to the executive to fire is the command for range or elevation, the command FIRE, or the command RESUME FIRING.

b. The executive's command to the chiefs of section to fire is the command FIRE or RESUME FIRING.

c. The command to fire a normal barrage is BARRAGE.

41. HOLDING FIRE.

a. The officer conducting fire may command DO NOT LOAD immediately preceding the command for range or elevation. DO NOT LOAD is then part of the command for range or elevation. The command to the executive to fire (revoking the command DO NOT LOAD) is a repetition of the range or elevation, or a new command for range or elevation.

b. The officer conducting fire may give AT MY COMMAND immediately following the method of fire. Then AT MY COMMAND is part of the method of fire. The executive does not repeat the command. When pieces are ready to fire, he reports "Battery is ready," and fires at the command FIRE. AT MY COMMAND continues in effect until a command is given for a new method of fire not followed by AT MY COMMAND.

42. CEASING FIRE.

a. The command CEASE FIRING normally is given by the executive, but in an emergency may be given by anyone present. At this command, firing will cease immediately. If the command originated from the officer conducting fire and the piece is loaded, the executive reports "No. 1 (or other piece) loaded." If the command originated at the battery position, a report of this command and the reason for it is rendered. Firing is resumed at the announcement of range or elevation.

b. The command SUSPEND FIRING is given only to effect a temporary halt in firing on a prearranged schedule. At this command firing is stopped, but settings continue to be altered in conformity with the schedule. If a piece is loaded, the executive reports to the officer conducting fire, "No. 2 (or other piece) loaded." Firing in accordance with the schedule is resumed at the command RESUME FIRING.

c. Except in continuous fire, a change of data following the command for range or elevation serves as a signal to stop all fires previously ordered. Firing is resumed at the new announcement of range or elevation. In continuous fire, changes in data are so applied as not to stop the fire or break its continuity.

43. PIECES TO FOLLOW COMMANDS. Designated pieces follow fire commands; for example: BATTERY ADJUST, NO (S). (SO-AND-SO) ADJUST, RIGHT (LEFT) (CENTER) ADJUST. Pieces that have not been following fire commands begin to follow when the officer conducting fire commands BATTERY ADJUST or RIGHT (LEFT) (CENTER) ADJUST.

44. INITIAL AND SUBSEQUENT COMMANDS.

a. The initial fire commands include all data necessary for laying, loading, and firing the pieces. Subsequent commands include only such data as are changed, except that the range or elevation is always announced. When another observer takes over the conduct of fire during a mission, he will, if practicable, continue the mission from the last round observed or issue complete initial commands if necessary. In such case the fire-direction center or battery executive should check closely to determine that the announced commands appear appropriate to the mission. If advisable, proper authentication may be required of the new observer.

b. When a change is made in pieces to fire or the method of fire, or both, the commands for both elements are given. Decreasing or increasing the number of rounds in a method of fire does not constitute a change of method.

45. COMMANDS FOR INDIVIDUAL PIECE.

a. When more than one piece is being fired and individual commands are required for each piece, the command for each piece is preceded by NO. (SO-AND-SO); for example: ELEVATION NO. 1, 350; NO. 2, 340; NO. 3, 330; NO. 4, 320.

b. When more than one piece is being fired, a change for an individual piece is preceded by the command NO. (SO-AND-SO). A change for an individual piece is announced and set after any change of the same element is given for all pieces (par. 100).

46. PROJECTILE. The command for shell is SHELL HE (SMOKE) (GAS). If more than one type of HE (smoke) (gas) shell is available at the position, the command is SHELL HE (SMOKE) (GAS), MARK I (or other type designation).

47. CHARGE. With ammunition that has numbered charges, the command is CHARGE 4 (or other number). When both green bag and white bag powder for a given charge are at the position, the command for charge is followed by GREEN (WHITE) BAG. With ammunition of supercharge, normal charge, and reduced charge, the

command for charge is SUPERCHARGE, NORMAL CHARGE, or REDUCED CHARGE. If more than one type of normal charge is available, the command NORMAL CHARGE M8 (or other designation) is given.

48. FUZE.

a. The command for percussion fuze is FUZE QUICK (DELAY). When two types of quick fuze are available, the command FUZE QUICK is given for the type of fuze generally used (M48, M51). For the other type of fuze, the command FUZE QUICK M54 (or other designation) is given.

b. The command for time fuze is CORRECTOR (SO MUCH), TIME (SO MUCH); or CORRECTOR (SO MUCH), FUZE RANGE (SO MUCH). (*Note:* Corrector is not announced unless fuze setter is used.) The command for a change in corrector setting or time setting is a new command for corrector or time. A command for fuze range is required only in initial commands; subsequently the command for range covers both fuze range and range. By prearrangement within a battalion, all time corrections may be included in time settings, and the command for corrector omitted; with this prearrangement, the corrector scale (if any) is set habitually at 30.

c. In time bracket fire, when fuze range for the charge used does not appear on the fuze setter, firing battery personnel determine the time setting corresponding to the announced range or fuze range (see TM 9–524 and TM 9–526). The executive then commands TIME (SO MUCH).

d. When a ladder is to be fired with time fuze, the officer conducting fire announces all times consecutively. The executive initially repeats only the first time commanded and subsequently repeats the *second time* after the first round has been fired, and so on.

49. DIRECTION. The battery may be laid initially by: a *Y*-azimuth, a base angle, an aiming point and a deflection, a target and a lead, an airplane, or a high air burst.

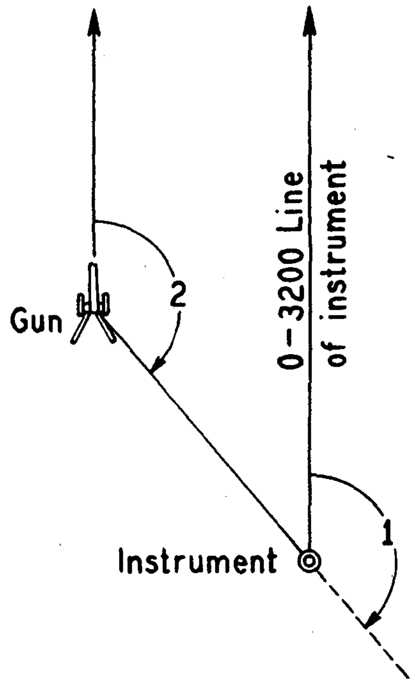
50. PARALLEL SHEAF—RECIPROCAL LAYING.

a. General. A piece is laid reciprocally on an instrument as follows: the 0-3200 line of the instrument is established in direction; the operator, using the upper motion, turns the vertical hair to the sight of the piece, reads the azimuth and micrometer scales, and (subtracting 3200 mils if necessary) announces the reading. Using this reading for

a deflection and the instrument as an aiming point, the gunner lays the piece. By this method an instrument may be laid reciprocally on a piece or on another instrument; a piece may be laid reciprocally on another piece. If time permits, reciprocal laying is repeated until successive readings are within 1 mil (fig. 12).

b. Form sheaf parallel. The command to the executive is, ON NO. 2 (or other piece) FORM SHEAF PARALLEL. The executive does not repeat the command. He forms the sheaf parallel by reciprocal laying.

c. On No. 2 lay parallel. The base piece is laid for direction; the executive may command, for example: ON NO. 2 LAY PARALLEL. The gunner of the base piece lays the other pieces reciprocally.



NOTE:
Angle 1, the reading on the instrument, is equal to angle 2, the deflection on the sight.

Figure 12. Reciprocal laying.

51. Y-AZIMUTH (COMPASS) (fig. 13).

a. The command to the executive is COMPASS (SO MUCH). The executive does not repeat this command.

b. The executive sets up an aiming circle away from magnetic metals (par. 31) and in a place when it can be used as an aiming point for all pieces (fig. 13). The executive:

(1) Subtracts the announced *Y*-azimuth (angle 1) from the declination constant of the aiming circle (adding 6400 to the declination constant if necessary).

(2) Sets the remainder (angle 2) on the azimuth and micrometer scales of the aiming circle.

(3) Releases the compass needle and centers it with the lower motion. (The 0–3200 line of the instrument now coincides with the announced *Y*-azimuth.)

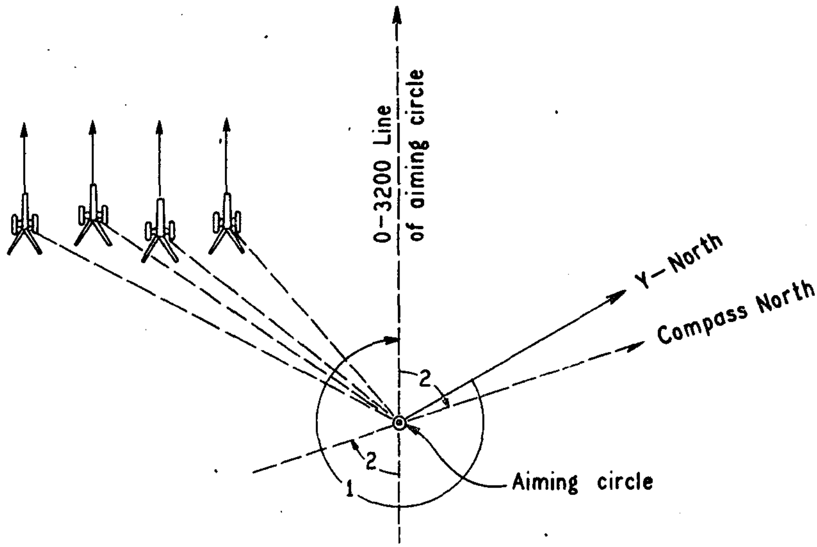


Figure 13. Laying the battery on a Y-azimuth, using the aiming circle.

(4) Lays each piece reciprocally (par. 50). His commands are, for example: AIMING POINT, THIS INSTRUMENT, DEFLECTION NO. 1, 3091; NO. 2, 2738; NO. 3, 2369; NO. 4, 2045.

(5) Commands, for example: AIMING POINT, AIMING POSTS, REFER.

c. If he has a compass but does not have an aiming circle, the executive sets up the compass away from magnetic metals and in a place where it can be used as an aiming point for the base piece. The executive:

(1) Measures the *Y*-azimuth to the sight of the base piece.

(2) Subtracts the announced *Y*-azimuth from the *Y*-azimuth which he has measured (adding 6400 if necessary).

(3) Using the remainder as a firing angle and the compass as an aiming point, lays the base piece.

(4) Lays the other pieces reciprocally on the base piece.

(5) Commands, for example: AIMING POINT, AIMING POSTS, REFER.

52. BASE ANGLE. The command to the executive is BASE ANGLE (SO MUCH). The executive does not repeat this command. He sets up an instrument on the orienting line where it can be seen by all pieces. The executive sets the base angle on the azimuth and microm-

eter scales of the instrument and, using the lower motion, sights along the orienting line. The 0–3200 line of the instrument is now parallel to the direction in which the pieces are to be laid. He then lays the pieces reciprocally (par. 50).

53. AN AIMING POINT AND A DEFLECTION.

a. The command to the executive is AIMING POINT (SO-AND-SO), DEFLECTION (SO MUCH).

b. The executive may accomplish the laying by computing a shift from a previous laying, by repeating the command and computing individual shifts to lay the battery parallel, or by laying his instrument or a designated piece on the deflection commanded and laying the remaining pieces by reciprocal laying.

54. TARGET AND A LEAD. The command for a target and a lead and the execution of the command are prescribed in the appropriate service of the piece manual and in FM 6–140.

55. AN AIRPLANE OR HIGH AIR BURST. No specific command is prescribed. The executive may lay the battery initially for direction by sighting with an instrument on an airplane or high air burst over the target area.

56. CHANGES IN DIRECTION. The command is RIGHT (LEFT) (SO MUCH), or BASE DEFLECTION RIGHT (LEFT) (SO MUCH).

57. DISTRIBUTION.

a. The command for distribution is ON NO. 2 (or other piece) OPEN (CLOSE) (SO MUCH).

b. For handling irregularities in distribution resulting from the emplacement of pieces in staggered positions, see paragraphs 95–100.

58. SITE. The command for site is SITE (SO MUCH). The command for a change in site is UP (DOWN) (SO MUCH).

59. PIECES TO FIRE. The command to fire all pieces is BATTERY. The command to fire a pair of pieces is RIGHT (LEFT) (CENTER), indicating the right (left) (center) pair of pieces. The command to fire a piece or any other combination of pieces is NUMBER (S) (SO-AND-SO). The command FIRE AT WILL directs all pieces to fire.

60. METHODS OF FIRE. Methods of fire are: salvo fire, volley fire, continuous fire, single piece, by piece at my command, fire at will, ladder fire, and zone.

61. SALVO FIRE.

a. The command for a salvo is RIGHT (LEFT), which indicates the flank from which the pieces are to be fired successively. The command to change the normal interval of 2 seconds is AT (SO MANY) SECONDS, given after the RIGHT (LEFT). The command AT (SO MANY) SECONDS continues in effect until the method of fire is changed or another interval is commanded.

b. The executive gives the command FIRE when he sees that the pieces will be ready to fire in turn; each piece is then fired at command of its chief of section. If a piece is obviously in error or is very slow, the executive calls the piece out, has the remaining pieces fire, and reports to the officer conducting fire, for example: "No. 3 did not fire."

62. VOLLEY FIRE.

a. The command for volley fire is (SO MANY) ROUNDS. Fire is opened at the executive's command FIRE, given immediately after the range or elevation, unless a command for holding fire is prescribed. Each designated piece fires the specified number of rounds, as rapidly as is consistent with accuracy, without regard to other pieces.

b. The command for a specific time interval is (SO MANY) ROUNDS AT (SO MANY) SECONDS, or (SO MANY) ROUNDS PER MINUTE.

63. CONTINUOUS FIRE. The command for continuous fire is CONTINUOUS FIRE RIGHT (LEFT) AT (SO MANY) SECONDS. If fire is by single piece, RIGHT (LEFT) is omitted. Continuous fire, when executed by more than one piece, is a succession of salvos, the pieces being fired consecutively at the interval designated in the command. CONTINUOUS FIRE remains in effect until the method of fire is changed or until the command CEASE FIRING is given. Changes of data are applied so as not to stop the fire or break its continuity.

64. SINGLE PIECE. The command is NO. (SO-AND-SO). The executive repeats the command and gives the command FIRE when he sees that the piece is ready.

65. BY PIECE AT MY COMMAND. The command is BY PIECE AT MY COMMAND. The executive repeats this command. When the battery is ready to fire, he reports, "Battery is ready." When each command to fire is received, he commands NO. (SO-AND-SO) FIRE.

66. FIRE AT WILL. The command is TARGET, (SO-AND-SO), FIRE AT WILL. If a method of close defense has been prearranged, the command is simply FIRE AT WILL.

67. LADDER FIRE. The command to the executive is LADDER. It is followed by three ranges 300 yards apart, or by ELEVATION (QUADRANT) and three elevations 3 *c*'s apart. The executive has the designated piece fire one round at each of the three ranges or elevations, in the sequence of their announcement. At the command REPEAT LADDER, the same ranges or elevations are fired.

68. SHIFTING FIRE. When the width of the target is too great to be covered with an open sheaf, it should be attacked by successive shifts. The number of sheafs required is determined by dividing the width of the target by width of area covered by an open sheaf (par. 90a). If this result is fractional, the next greater whole number is used. The amount of each shift is determined by dividing the difference between the width of the target and the width of area covered by an open sheaf, by one less than the number of sheafs required to cover the target. The result is converted to mils at the target range.

69. ZONE.

a. When the elevation scale or gunner's quadrant is to be used, the command is ZONE (SO MANY) MILS. It is followed by ELEVATION (QUADRANT) (SO MUCH)—the elevation (quadrant) for the center of the zone. The executive has the designated pieces fire at five elevations, in the sequence: center elevation, the elevations differing from the center elevation by the announced number of mils in any order, and the elevations (to the nearest mil) midway between the center elevation and the other two. For example, if the command is ZONE 10 MILS, ELEVATION 190, the executive has the designated pieces fire at 190, 200, 180, 185, and 195.

b. When the range scale is to be used, the command is merely ZONE. It is followed by the range for the center of the zone. The executive has the designated pieces fire at the center range, the ranges 100 yards over and short of the center and the ranges 50 yards over and short of the center.

70. QUADRANT, ELEVATION SCALE, RANGE SETTING. The command for the use of the gunner's quadrant is QUADRANT, for the

use of the elevation scale, ELEVATION. The command for range is, for example: 4800. QUADRANT or ELEVATION continues in effect until a different method of laying for range is announced. The command for elevation is, for example: ELEVATION 178. The command SAME ELEVATION may be given, but only when more than one piece is firing and the pieces are laid at different elevations. When the officer conducting fire transmits ranges, and the appropriate range drum is not in position on the pieces, firing battery personnel convert each command for range to an elevation using tabular firing tables or GFT (TM 9–524 and TM 9–526).

71. PREARRANGED FIRES.

a. Written data for prearranged concentrations, schedules, and barrages usually are sent to the executive by data sheet (figs. 141 and 147). These data are kept up to date with latest available corrections.

b. Data for barrages are furnished by fire-direction center on data sheets, if time permits, but may be transmitted to batteries by telephone or radio when commands are to be executed at once. Any special instructions regarding the firing, such as shifts, fires to be repeated, and rates of fire, appear in the REMARKS column.

c. The normal barrage may be started by the piece sentinels or by the command BARRAGE. When not firing other missions and unless otherwise directed, the battery is kept laid on its normal barrage.

72. RECORDING BASE DEFLECTION.

a. Before base deflection is recorded the battery must be laid parallel (except as authorized in subparagraph b below). The executive may have base deflection recorded after the initial laying or after a change of aiming points. The officer conducting fire may order base deflection recorded at any time; for example, after registration. Base deflection will not be changed thereafter except on command of the officer conducting fire. The command is RECORD BASE DEFLECTION. Only one base deflection is on record at any time; upon the command RECORD NEW BASE DEFLECTION, any previous base deflection is discarded.

b. In case the officer conducting fire desires to have base deflection recorded with the pieces laid other than parallel, he adjusts the sheaf, and then commands AS LAID, RECORD BASE DEFLECTION.

c. When the officer conducting fire desires to verify deflection later, he commands RECORD INSTRUMENT DIRECTION, followed by commands for corrector, time, and elevation, on completion of the base point (check point) registration. These commands are based

on the results of the registration. The executive fires an air burst at a site which will surely allow the burst to be seen above the crest in front of the battery. The 0-3200 line of the instrument is placed on the burst with the *lower motion.* Having marked the position of the instrument with a stake, referred to an object, and recorded the reading, the executive reports "Instrument direction recorded (base point) (check point No. 1)."

73. MEASURING COMPASS (fig. 14).

a. The officer conducting fire may command MEASURE COMPASS. The executive does not repeat the command. He sets up the aiming circle away from magnetic metals, where it can be used as an aiming point for the base piece, and with 0-3200 line approximately in the direction of fire. The executive lays his instrument reciprocally on No. 2 (or base piece). Using the upper motion, he then centers the needle. He subtracts the reading of the scales from the declination constant (plus 6400 if necessary) and reports "Compass (so much)."

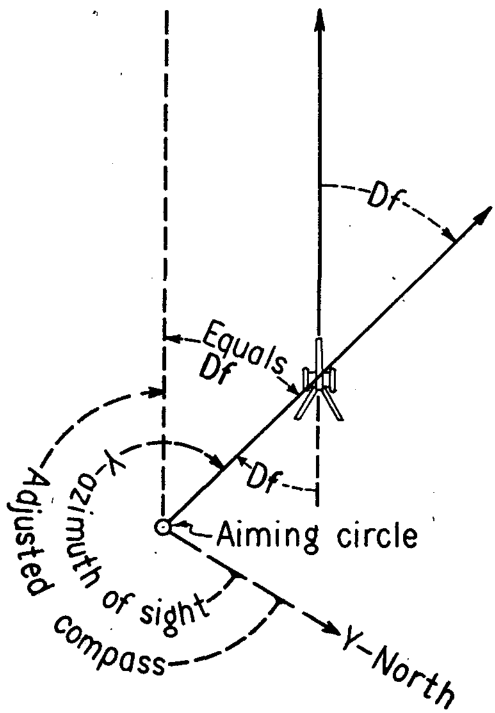


Figure 14. Measuring the compass.

b. If the executive has a compass instead of an aiming circle (or as an alternate method for the aiming circle), he:

(1) Places the compass away from magnetic metals and in a place where it can be used as an aiming point for the base piece.

(2) Measures the *Y*-azimuth to the sight of the base piece.

(3) Commands NO. 2 (base piece), AIMING POINT THIS INSTRUMENT, MEASURE DEFLECTION.

(4) Subtracts the resulting deflection from the *Y*-azimuth which he has measured. With compass on the left of the base piece, he adds 6400 if necessary to get a positive number. With compass on the right

of the base piece, he adds 3200 if necessary to get a positive number or if the difference was less than 3200; he subtracts 3200 if the difference was greater than 3200.

(5) Reports "Compass (so much)."

74. MEASURING BASE ANGLE. The command is MEASURE BASE ANGLE. The executive does not repeat the command. With the base piece laid on base deflection he sets up his instrument on the orienting line where it can be used as an aiming point for the base piece with the 0-3200 line of the instrument approximately in the direction of fire. The executive lays his instrument reciprocally on No. 2 (or base piece). Using the upper motion he then sights along the orienting line. He reports the reading of the azimuth and micrometer scales as "Base angle (so much)." The base angle is never greater than 3200 mils.

75. MEASURING DEFLECTION. See the appropriate field manual on service of the piece.

76. REPORTING ADJUSTED COMPASS. After an adjustment, the officer conducting fire may command REPORT ADJUSTED COMPASS. Upon receiving this command the executive checks the sight of the adjusting piece and reads the deflection. The executive then determines the difference between this deflection and the initial deflection, applies it to the *Y*-azimuth on which the piece was previously laid, and reports "Adjusted compass (so much)." Note that an *increase* (decrease) in *deflection* causes a *decrease* (increase) in *compass.*

77. REPORTING ADJUSTED DEFLECTION. After an adjustment of the base piece, the officer conducting fire may command REPORT ADJUSTED DEFLECTION. The executive does not repeat the command. He compares the deflection on the sight of the base piece with the base deflection and reports "Base deflection right (left) (so much)."

78. EXAMPLES OF FIRE COMMANDS. In the examples which follow, a particular weapon is indicated in most cases, but the commands are applicable, in general, to all calibers.

a. Precision adjustment for registration and for recording base deflection and instrument direction for observed fire chart; 105-mm howitzer.

(1) Commands:

BATTERY ADJUST
SHELL HE
CHARGE 4
FUZE QUICK
COMPASS 1450
SITE 305
NO. 2 ONE ROUND
ELEVATION 210.

(2) The executive does not repeat COMPASS 1450. After repeating the commands for ammunition, he uses one of the methods described in paragraph 51. He then repeats the other commands, and adds FIRE.

(3) To record instrument direction on the completion of the registration, the command is:

RECORD INSTRUMENT DIRECTION
TIME 11.2
ELEVATION 218.

(4) The executive requires at least 20 mils site to observe a burst above the mask. He commands for example:

TIME 11.2
SITE 340
NO. 2 ONE ROUND
ELEVATION 218.

An instrument with 0-3200 line in the direction of fire is set up near the base piece; the executive commands FIRE.

He moves the cross hairs to the *burst,* refers to an object, and reports "Instrument direction recorded."

b. Check deflection from recorded instrument direction; 105-mm howitzer.

(1) Commands:

CHECK DEFLECTION, CHECK POINT NO. 2
CHARGE 4
BASE DEFLECTION RIGHT 280
TIME 15.7
ELEVATION 312.

(2) The executive lays his instrument on the check point by use of the previously recorded instrument direction. He gives a command for site that will enable him to observe a burst above the mask. He commands for example:

NO. 2 ADJUST
SHELL HE
CHARGE 4
CORRECTOR 30, TIME 15.7
BASE DEFLECTION RIGHT 280
SITE 350
NO. 2 ONE ROUND
ELEVATION 312
FIRE.

The burst is observed 7 mils right of the vertical cross hair. He applies a correction of left 7 to the base deflection shift and reports "Adjusted deflection check point No. 2, base deflection right 273."

(3) At the fire-direction center, the reported adjusted deflection is compared with map data and new corrections determined.

c. Shift from base deflection, zone fire; 105-mm howitzer.

(1) Commands:

BATTERY ADJUST
SHELL HE
CHARGE 5
FUZE DELAY
BASE DEFLECTION RIGHT 120
ON NO. 2 CLOSE 3
SITE 307
BATTERY ONE ROUND
ZONE 7 MILS
ELEVATION 268.

(2) If chiefs of section are to fire the zone, the executive repeats all commands and adds FIRE.

(3) If the executive is to fire the zone, he repeats all of the commands except ZONE 7 MILS, and adds FIRE. After the volley at 268 is fired, he commands the next elevation and FIRE; for example:

261 FIRE
275 FIRE
271 (or 272) FIRE
264 (or 265) FIRE.

d. Use of aiming point; 75-mm howitzer.

(1) Commands:

BATTERY ADJUST
SHELL HE
CHARGE 3
FUZE DELAY
AIMING POINT, SMOKESTACK, LEFT FRONT
DEFLECTION 2840
ON NO. 3 CLOSE 4
SITE 295
CENTER RIGHT
ELEVATION 270.

(2) The executive repeats all commands and at the proper time adds FIRE.

(3) To change data after the first salvo, the commands may be:

RIGHT 20
286.

e. Shift from last target and change to time shell; 105-mm howitzer.

(1) Commands:

SHELL HE
CHARGE 3
CORRECTOR 30, TIME 18.4
LEFT 60

ON NO. 2 OPEN 2 (to allow for difference in range from last target)

SITE 315
CENTER RIGHT
ELEVATION 405.

The executive repeats all of the commands and at the proper time adds FIRE.

(2) To change data after the first salvo, the commands may be:

LEFT 15
DOWN 5
TIME 19.6
435.

The executive repeats all commands and at the proper time adds FIRE.

f. Laying by base angle and recording base deflection without adjustment.

(1) Commands:

BASE ANGLE 1460
RECORD BASE DEFLECTION.

(2) *The executive converts the above commands, thus:*

AIMING POINT, THIS INSTRUMENT
DEFLECTION NO. 1, 463; (and so on)
AIMING POINT, AIMING POSTS
REFER
RECORD BASE DEFLECTION.

(3) The executive reports "Base deflection recorded."

g. Precision adjustment on a check point; 155-mm howitzer.

NO. 2 ADJUST
SHELL HE
CHARGE 4, GREEN BAG
FUZE QUICK
BASE DEFLECTION LEFT 140
NO. 2 ONE ROUND
ELEVATION 285.

The executive repeats all of the commands and adds FIRE.

h. Bracket adjustment; 105-mm howitzer, M2. The officer conducting fire announces range. Ricochet fire has been found impracticable in the area. A graphical firing table is being used at the battery position to convert fuze range to time, and range to elevation.

(1) Commands:

BATTERY ADJUST (The battery has been firing a mission conducted through the fire-direction center.)

SHELL HE
CHARGE 6
FUZE RANGE 6600
BASE DEFLECTION LEFT 120
ON NO. 2 OPEN 3
SITE 310
CENTER RIGHT
6600.

The executive commands:

(The battery has been following commands, and HE shell with charge 6 has been in use.)

TIME 20.6
BASE DEFLECTION LEFT 120
ON NO. 2 OPEN 3
SITE 310
CENTER RIGHT
ELEVATION 318.

At the proper time he adds FIRE.

(2) To change data after the first salvo, the commands may be:

RIGHT 30
UP 10
6200.

The executive commands:

RIGHT 30
UP 10
TIME 19.1
292.

At the proper time he adds FIRE.

i. Firing for a center of impact to be located by an air observer; 155-mm howitzer, M1.

(1) The officer conducting fire commands:

NO. 2 ADJUST
SHELL HE
CHARGE 5, GREEN BAG
FUZE QUICK
BASE DEFLECTION RIGHT 260
NO. 2 FOUR ROUNDS
DO NOT LOAD, ELEVATION 380.

The executive repeats all of the commands.

(2) When the air observer directs the battery to fire, the officer conducting fire commands: 380. The executive repeats the command and adds FIRE.

j. Firing a ladder; 105-mm howitzer.

(1) The officer conducting fire commands:

NO. 2 ADJUST
SHELL SMOKE
CHARGE 4
CORRECTOR 30
TIME 12.9, 11.6, 10.3
BASE DEFLECTION
SITE 300
NO. 2, LADDER
ELEVATION 297, 269, 242.

(2) The executive repeats the commands as given except TIME 11.6, 10.3; LADDER; and ELEVATION 297, 269, 242. For these he substitutes NO. 2, ONE ROUND, ELEVATION 297, FIRE; TIME 11.6, ELEVATION 269, FIRE; TIME 10.3, ELEVATION 242, FIRE.

Note: The command ELEVATION may be given for each round to avoid errors.

k. Transfer of fire at a range of 16,930 yards; 155-mm gun; fuze quick, time on target; battery front 200 yards, uniform.

(1) Commands:

BATTERY ADJUST
SHELL HE
SUPERCHARGE
FUZE QUICK
BASE DEFLECTION RIGHT 312
BATTERY THREE ROUNDS
DO NOT LOAD, QUADRANT 280

* * * *

TIME ON TARGET, three minutes from . . . . *NOW*, QUADRANT 280.

(2) The executive determines the time of flight to be 35 seconds. He repeats all commands except "TIME ON TARGET, three minutes from . . . . *NOW*," and announces the second QUADRANT 280 so as to coordinate the time of loading to insure that the projectile will not be in the bore longer than 30 seconds prior to firing. He gives the command FIRE at the appropriate time, from the count by fire-direction center.

PART THREE

Paragraphs 79 to 169, inclusive, pages 44 to 150, inclusive, are superseded by Change 2, FM 6-40, 20 February 1947, which will be found at the back of this manual.

PART FOUR
SURVEY

CHAPTER 1
SURVEY PRINCIPLES

Section I. BASIC PRINCIPLES

170. GENERAL.

a. Whereas the observed fires of a battery can be maneuvered without a chart, a firing chart or an observed fire chart is essential for maneuvering the observed fires of battalions and larger units. A firing chart is necessary for all unobserved fires.

b. A firing chart is a map, photomap, or grid sheet on which are plotted to a known scale the relative horizontal and vertical locations of the base point, check points, targets, batteries, and any other data necessary for the preparation of fire.

c. The effectiveness of artillery fires and the amount of ammunition which must be expended in order to insure effective fire are affected by the relative accuracy and completeness of survey. Every effort must be made to augment survey by the following:

(1) Vertical photographs.

(2) Oblique photographs.

(3) Stereoscopic pairs (or strips).

d. The purpose of field artillery survey is to determine the horizontal and vertical locations of points on the ground in order that they may be placed on the firing chart, and to provide a means of orienting the pieces on the ground. The accuracy of the chart should be checked by firing as soon as possible. (See par. 72 for recording direction thus established.)

e. An observed fire chart is a chart on which the location of points and the orientation of the pieces have been determined by firing, rather than by survey.

171. OBSERVED FIRE CHART. Observed fire charts which are based on registration are used before the firing chart is completed. When

no topographical information is available, an arbitrary location on a chart is selected as the base point. The registration data of each battery, converted to back azimuth and range, are then plotted from the base point. When a map or photomap is available and the base point can be identified on it by inspection, the map or photomap is used as the observed fire chart; the battery positions may be located either by inspection or by plotting back azimuth and range. The observed fire chart is used for massing observed fires based on an adjustment by one of the batteries. As soon as survey is completed, the observed fire chart is replaced by the firing chart in order that unobserved and surprise fires may be executed.

172. FIELD ARTILLERY SURVEY. Field artillery survey is not an end in itself, but is rather a means to an end—namely, furnishing to the fire-direction center such information as will enable the fire-direction center to determine data necessary to place the fire of any or all pieces of the unit on any point within range. All survey should be performed with a definite goal and should be based upon a carefully formulated plan. It should be planned to preclude wasted effort. Survey is not concluded as soon as the firing chart is complete; it is never ending and ceases in one area only to commence in another. Survey is continued in order to check and improve earlier survey, augment target locations, locate alternate positions, and extend common control.

173. THE BASIS OF THE FIRING CHART.

a. The type of firing chart used depends upon the amount of topographical information available in the form of maps and photomaps. When a map or photomap of suitable scale is available, it is used as the firing chart initially. For convenience, a copy of the survey (on a map) may be reproduced on a grid sheet, which may then be used as a firing chart. The accuracy of the map or photomap is checked by survey as soon as possible (par. 294). If the map or photomap is proved inadequate by the survey, the grid sheet becomes the firing chart, with details transferred from the map or photomap to the grid sheet by restitution when necessary. When the only map available has a scale too small to permit use of the map as a firing chart, basic information, upon which to initiate a grid sheet survey, may be taken from the map. This basic information should be coordinated with and supplemented by control information obtained from the higher survey echelons in the area. This procedure will permit delivery of fire on targets reported by coordinates on the small scale map.

b. When an available map or photomap has been checked by survey or firing and found to be accurate, it is suitable for use as a firing

chart, and a large part of the survey will have been accomplished by the map maker or camera. In this case, the firing chart is constructed by locating on the existing survey the base point, check points, targets, batteries, and other critical points. When maps or photomaps are not available, the field artillery surveyor must perform the entire survey, locating, in their relative positions on a blank grid sheet, the points needed for the firing chart. This process, which in the final analysis is the making of a map with incomplete coverage of the target area, is slow and laborious as compared with survey for use on a map or photomap.

c. The ideal equipment for use in firing observed and unobserved fires—ranging from use of a single gun to employment of masses of artillery—includes all of the following: a first class map of a scale not smaller than 1/50,000 (and preferably 1/25,000) which was constructed by accurate survey; a mosaic prepared from recent photographs; current stereoscopic intelligence photographs of the target area; and oblique photographs, if procurable. The completeness of available photographic coverage is influenced by weather, planning, and availability of airplanes.

174. SURVEY OPERATIONS INVOLVED IN CONSTRUCTION OF A FIRING CHART. To construct a satisfactory firing chart, any information shown on the chart must be supplemented by additonal information obtained by survey. To obtain this information some or all of the operations listed below will be necessary:

a. Determination of any basic chart information which is necessary to tie the survey to the chart or which will facilitate the survey by making use of control afforded by the chart. Such basic information includes chart scale, chart location and altitude of ground points, and chart azimuth of ground lines.

b. Determination of relative horizontal location of batteries, targets, and observation posts.

c. Determination of relative vertical location of batteries, targets, and observation posts.

d. Determination of base angles, in order to lay the guns in a known direction.

e. Provision for uniform declination of instruments.

175. DIVISION OF SURVEY OPERATIONS.

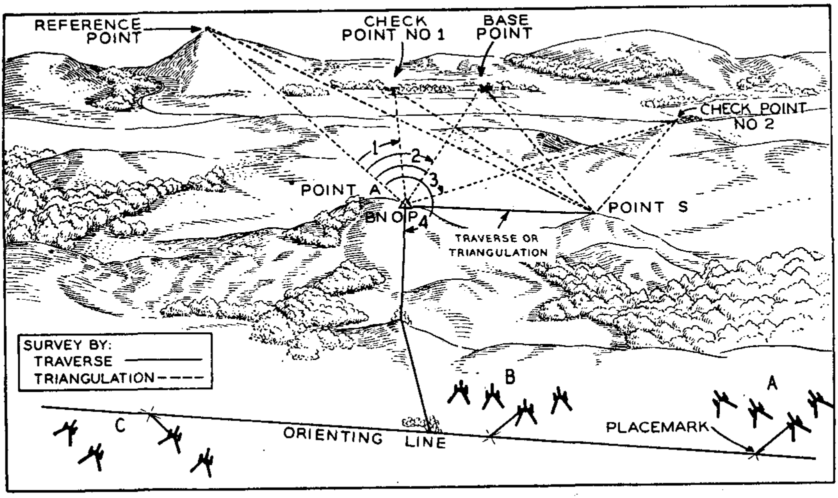
a. The survey operations listed above logically break down into three phases which are performed by details as follows:

(1) TARGET AREA SURVEY. The detail conducting the target area survey determines the relative horizontal and vertical location

of the base point, check points, targets, key terrain features, and observation posts. The location of points in the target area will in most cases be determined by the use of a target area base, *which is oriented by a line of direction to a reference point preferably in the target area. This method of orientation insures the proper tying together of all points in the target area.* Target area survey is continuous throughout all operation.

(2) POSITION AREA SURVEY.

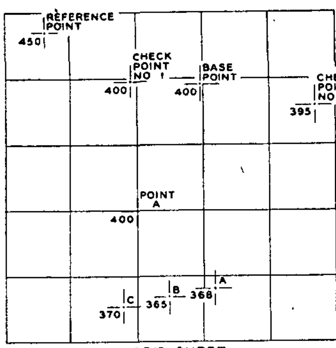
(*a*) The detail conducting the position area survey determines the relative horizontal and vertical locations of the batteries; establishes the orienting line, or lines, on the ground and determines their direction; and computes the base angles.



GROUND OPERATIONS

NOTE: (a) Angles 1, 2, 3, and 4 are angles measured in order to tie target area and position area to reference point. If division control were available, reference point would be a point furnished by division. The AS base is oriented by an instrument reading to the reference point.

(b) Some points whose locations have been determined are not plotted because they are of no value to fire direction personnel.

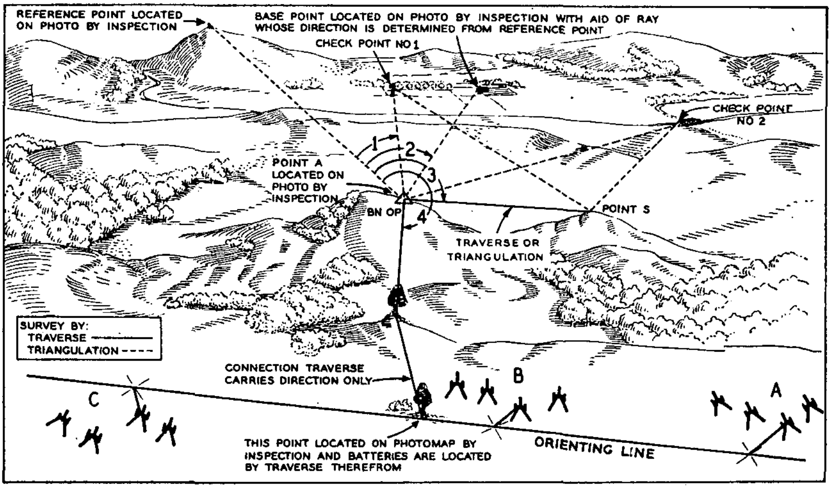


GRID SHEET

Figure 48. Battalion survey when a grid sheet is used.

(*b*) The survey should be run to the base piece of each battery or to the staked location selected for occupation by the base piece. In order not to delay the survey when information on the location of the base piece is not available at the time the survey is performed, control may be run to a point near the center of the battery position area and a stake placed at this point. On occupation of position, the executive will report to the fire-direction center the azimuth, distance, and difference in altitude from this stake to the location of the base piece of his battery, in order that the true position may be plotted on the firing chart.

The orienting line is materialized on the ground by means of stakes. Short stakes should be placed on the orienting line, over which the bat-



GROUND OPERATIONS

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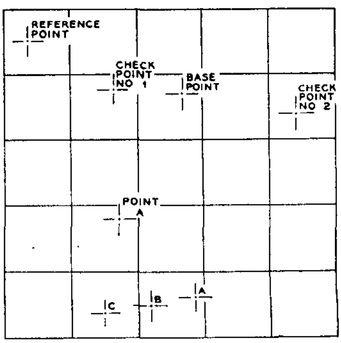
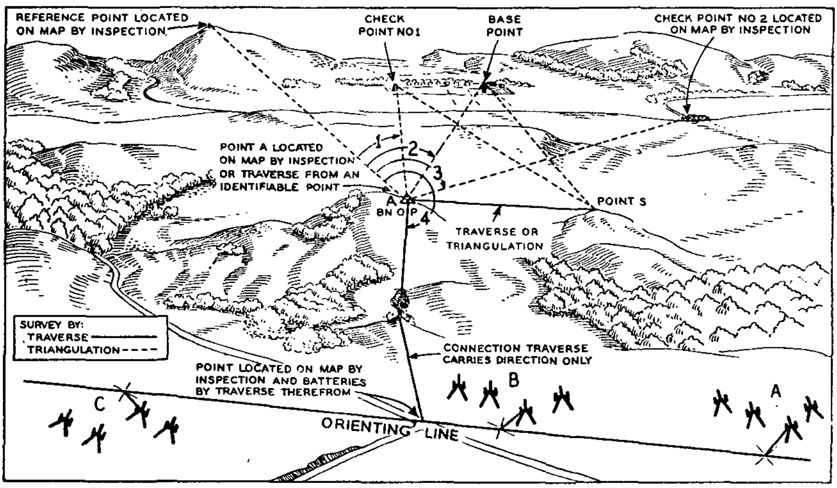


PHOTOMAP

Figure 49. Battalion survey when a photomap is used.

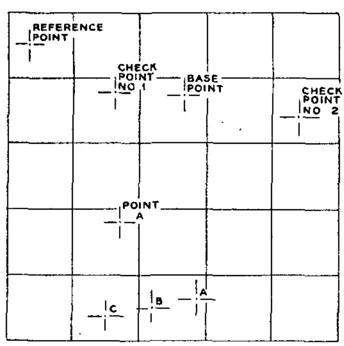
tery executives can place their instruments; tall stakes are placed on the orienting line within sight of each of the short stakes to furnish the battery executives a means of sighting along the orienting line. It is desirable that the stakes to be sighted on should be located at least 200 yards from the stakes over which the instrument is placed. Only one limitation must be observed in the selection of an orienting line: the line must pass conveniently near the battery which it serves. The direction of the orienting line with regard to the direction of fire is immaterial. The decision to establish one orienting line, or two, or three for a battalion is based partly on considerations of accuracy (a single orienting line is more accurate because fewer angles are measured) but to a greater extent on time and feasibility. Frequently, the



GROUND OPERATIONS

NOTE: (a) Angles 1, 2, 3, and 4 are angles measured in order to tie target area and position area to reference point. If division control were available, reference point would be a point furnished by division. The AS base is oriented by an instrument reading to the reference point.

(b) Some points whose locations have been determined are not plotted because they are of no value to fire direction personnel.



BATTLEMAP

Figure 50. Battalion survey when a battle map is used.

establishment of two or more orienting lines in preference to a single orienting line, will result in a great saving of time. It may be physically impossible to establish a single orienting line which will pass conveniently close to all batteries. The position area survey detail computes the base angle for each battery.

(3) CONNECTION SURVEY. The detail conducting the connection survey establishes the control required to tie the target area and position area together.

b. The determination of basic information is not assigned to any particular detail because its determination will vary with the type of firing chart used. Provision for uniform declination will usually be made by higher echelon than battalion; if not, the battalion survey officer must include it in his plan and assign it to the detail that can handle it with the greatest facility.

c. Figures 48, 49, and 50 illustrate battalion survey operations with various types of charts as the basis of the firing chart.

176. EFFECT OF REGISTRATION ON SURVEY OPERATIONS.

a. Registration does not affect the actual survey operations necessary to establish a firing chart except in so far as orientation of pieces

NOTE:

a. Grid sheet. Targets located with respect to base point by survey. Pieces located with respect to each other by survey. Pieces located with respect to base point and oriented by survey.

b. Photomap or battle map. Base point and targets located by inspection or survey. Pieces located by inspection or short traverse. Pieces tied to target area by photomap. Pieces oriented by survey.

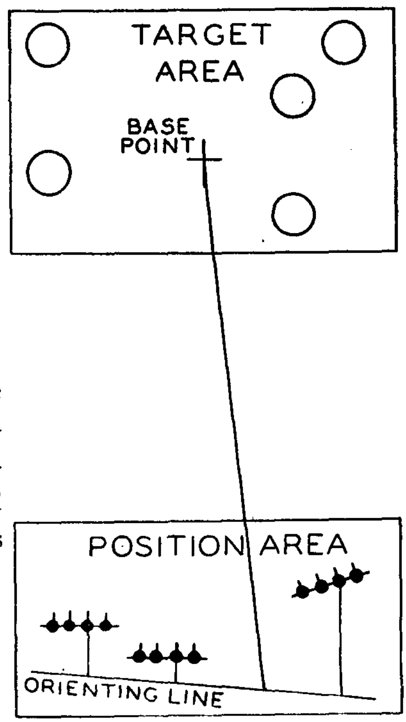
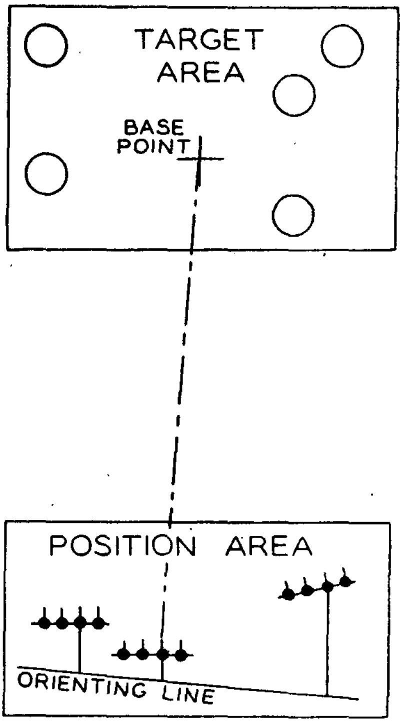


Figure 51. Registration prohibited.

and speed of opening fire are concerned. If registration is permitted, the pieces may be oriented by firing; whereas, if registration is prohibited, it is necessary to orient the pieces by survey. If time permits, it is desirable that the pieces be oriented by survey even when registration is permitted, and the data obtained from registration used to determine corrections to apply to the surveyed data.

b. Although registration does not affect the amount of survey necessary to establish a firing chart, it will affect the order in which the survey operations are performed. Priority is given to target area and position area survey inasmuch as the connection between the two can be established by firing if necessary.

c. Figures 51, 52, and 53 illustrate the relation between registration and survey.



NOTE:

a. Grid sheet. Targets located with respect to base point by survey. Pieces located with respect to each other by survey. Registering piece located with respect to base point and oriented by firing. Nonregistering pieces oriented by means of surveyed orienting line.

b. Photomap or battle map. Base points and targets located by inspection or survey. Pieces located by inspection or short traverse. Pieces tied to target area by photomap. Registering piece oriented by firing. Nonregistering pieces oriented through surveyed orienting line.

Figure 52. Registration limited.

NOTE:

a. Grid sheet. Targets located with respect to base point by survey. Pieces located with respect to base point and oriented by firing.

b. Photomap or battle map. Base point and targets located by inspection or survey. Pieces located by inspection or short traverse. Pieces tied to target area by photomap. Pieces oriented by firing.

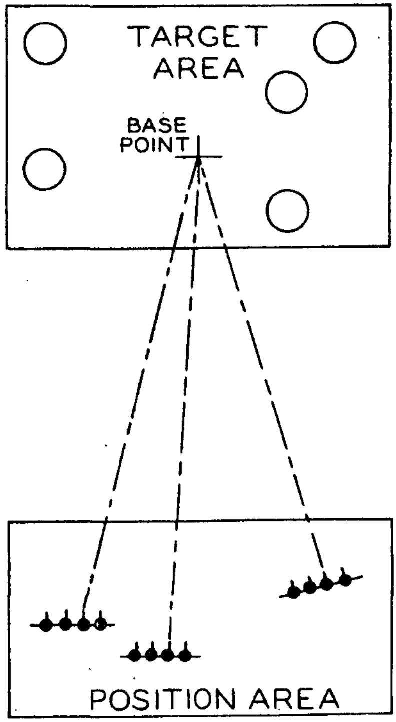


Figure 53. Registration unlimited.

Section II. ECHELONS OF SURVEY

177. SURVEY ECHELONS.

a. General. Although the flow of survey control is from higher to lower units, the subordinate unit never waits for this control before commencing its survey. Survey can be initiated on assumed control and converted to common control when common control is made available.

b. Corps.

(1) The corps topographic engineers are normally the highest echelon from which artillery survey sections obtain control. These engineers furnish control to the corps observation battalion or, in some cases, work in conjunction with the observation battalion in extending this control to divisions and separate battalions.

(2) The corps observation battalion normally furnishes common control to the artillery units of the corps. This is done by providing

each division and separate battalion with the coordinates, altitude, and ground location of two intervisible points; or the coordinates, altitude, and ground location of one of these points, and a *Y*-azimuth to the other point. One of these points is in the division or battalion position area, and the other is *preferably* in the target area. The observation battalion, in addition to furnishing this control, frequently coordinates with lower echelons the survey to be performed, in order to prevent duplication of survey effort.

The coordination and extension of control is accomplished through a corps survey information center established by the observation battalion. A record is maintained there of all survey control available in the corps sector. All requests for control should be made to the survey information center, and all survey data determined by units of the corps should be reported to it. Since the degree of accuracy of survey varies within the several echelons of survey, the source of any control obtained at the survey information center should be considered.

c. Brigade. The brigade survey is the same as that performed by division artillery. See subparagraph d below.

d. Division artillery. The purpose of division artillery survey is to place all the artillery of the division on the control which is common to all the artillery with the largest unit involved in the sector, in order that fire from its battalions can be massed either as a unit or in conjunction with the fire of other divisions and reinforcing artillery. To extend common control within the division, division artillery furnishes each battalion the coordinates, altitude, and ground location of a point in the battalion position area, and the *Y*-azimuth of a line from that point to a point (*preferably* in the target area) visible from the first. Instead of furnishing a *Y*-azimuth between the two points, the coordinates, altitude, and ground location of the second point may be furnished. Although the division artillery survey section establishes a division artillery survey information center where this control will be available, it is the responsibility of the division artillery commander, usually delegated as a duty of the division artillery survey officer, to ascertain that the control reaches each battalion. Division artillery also assists the battalions in transferring to common control by furnishing any available survey information in addition to that listed above.

e. Group and regiment. Neither the group nor the regiment performs any survey.

f. Battalion. The battalion is primarily interested in the construction of a firing chart which will permit the maneuver of the fire of the battalion and its batteries, and the delivery of unobserved fires.

g. Battery. Battery survey is an integral part of the battalion survey. Batteries will rarely perform an independent survey.

Section III. RESPONSIBILITY OF COMMANDERS FOR SURVEY

178. GENERAL. The commander is responsible that his unit be able to deliver the most effective support at all times. In order to facilitate the delivery of such support, the commander must:

a. Foresee the need for, plan for, procure, keep up to date, and distribute maps and photomaps, in order that the best possible chart is available for use as a firing chart.

b. Augment survey by obtaining proper coverages by aerial photographs, thus permitting the fixing and locating of targets beyond the normal means of survey by ground observation.

c. Continually seek observation for his unit. To exploit to the fullest the possibilities of artillery, all artillery units must not only have the ability to mass their fires but must also be able to observe the fires and apply any corrections which will increase their effectiveness.

d. Strive to obtain permission for his pieces to register. The increased effectiveness in fires obtained through registration should be impressed on supported commanders.

e. Establish a standing operating procedure and conduct training so that with minor changes this procedure will fulfill the requirements of most situations. Such items as assumed control on the grid sheet, loading charts for survey personnel, use of battery personnel, etc., readily lend themselves to standardization in a standing operating procedure.

f. Be familiar with the survey principles outlined in chapter 8, PART FOUR.

Section IV. SURVEY ELEMENTS IN THE FIELD ORDER

179. GENERAL. The artillery commander should not attempt to formulate the detailed survey plan. His survey officer is a specialist in this field and will formulate the detailed survey plan. The commander, however, should discuss with the survey officer the possible survey solutions so that a plan will be drawn up which will provide the most satisfactory results for the situation at hand.

180. SURVEY ELEMENTS IN THE FIELD ORDER. The following information, vital to the survey officer in formulating his plan, must be furnished by the commander.

a. Situation. It is essential that the survey officer be familiar with the situation, to include:

(1) Mission of the battalion.

(2) The status of registration.

(3) Time available for survey. The commander should always allow the maximum possible time for survey inasmuch as the time available will determine the relative accuracy of the firing chart.

(4) Normal and contingent zones.

b. Firing chart to be used. The decision as to which chart to use will depend upon topographical information available, time available, and the mission.

c. Available survey control furnished by higher echelons. The commander should inform the survey officer where and when survey control is to be made available. If no control is available, arrangement must be made for assumed control.

d. Availability of additional survey personnel.

e. Designation of base points and checks points. The base point, reference points, and check points should be pointed out on the ground and definitely identified by the survey officer and any other personnel who might be called upon to register on them. Such points should be identifiable on an air photograph. Sufficient check points must be designated throughout the target area to insure rapid and accurate massing of artillery.

f. Location of observation posts and fire-direction center. The locations of possible observation posts must be identified on the ground. The general location of the fire-direction center must be known to survey personnel.

g. Location of position areas.

CHAPTER 2

GRID SYSTEMS AND PLOTTING

Section I. FIRE CONTROL GRID

181. DESCRIPTION.

a. Military maps habitually have a rectangular grid superimposed. On battle maps the distance between adjacent grid lines ordinarily represents 1000 yards or 1000 meters. A grid of this type is known as a fire control grid; the term implies that the azimuth and scale are accurate.

b. The grid lines are numbered in accordance with the grid system to which the map conforms. Military maps may be provided with a standard grid for a particular theater of operations, or with an arbitrary grid used for a single map or for a limited area.

182. COORDINATES.

a. Writing coordinates. The distance in yards of any point east or west of the zero *Y*-line is the *X*-coordinate, and the distance north or south of the zero *X*-line is the *Y*-coordinate. In writing coordinates, the *X*-coordinate is written first and the *Y*-coordinate last, with a dash between, and the whole included in parentheses, thus: (804.729-1286.684). A decimal point is used to mark the division between thousands and hundreds of yards.

b. Designation of sheet. The name of the sheet of the map is part of the designation of a point by coordinates; when the identity of the map is clear to all concerned, its designation need not be given.

c. Abbreviated coordinates.

(1) If location to the nearest 10 or nearest 100 yards only is desired, or if the measurements cannot be made with greater accuracy, the digits indicating units or tens, respectively, may be omitted. Thus the coordinates of a point may be written:

(804.729-1286.684) . . . . to the nearest yard.
(804.73-1286.68) . . . . to the nearest 10 yards.
(804.7-1286.7) . . . . to the nearest 100 yards.

(2) It seldom is necessary to give more than two digits left of the decimal for each coordinate. The coordinates for the point given above then would be (04.729-86.684).

(3) If the point is fixed within an area 10,000 yards square, only one digit need be given before the decimal point of each coordinate. The coordinates of the point given above would be (4.729-6.684); to the nearest 100 yards (4.7-6.7). If a point is designated by abbreviated coordinates, the decimals and the dash may be omitted, thus (4767). These are known as hectometric coordinates.

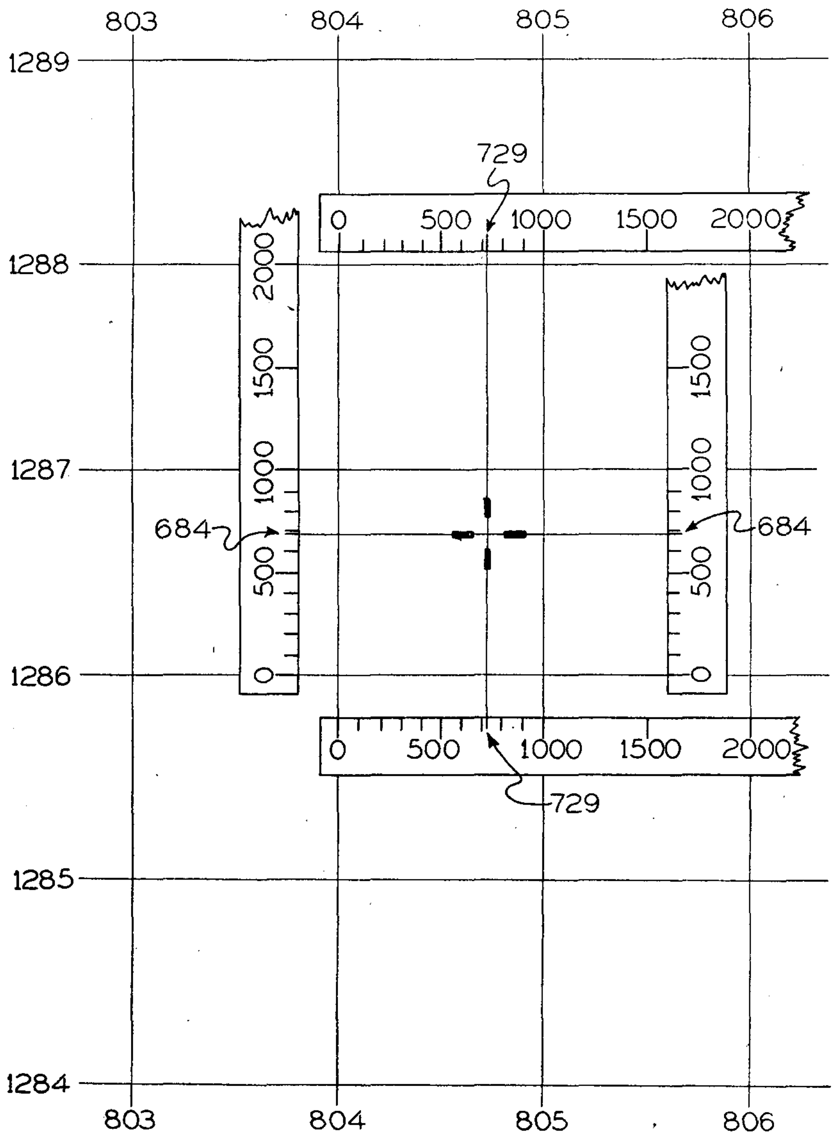


Figure 54. Plotting a point from coordinates on a normal grid.

183. PLOTTING A POINT FROM COORDINATES.

a. Normal grid. (See fig. 54.) To plot a point whose coordinates are (804.729-1286.684), place the zero of the scale on *Y*-line 804.000, and the 1000-yard point on *Y*-line 805.000. Holding the scale about one square above the approximate location of the point, mark 729 yards with a fine-pointed pencil or plotting needle. Place the scale about one square below the approximate location of the point, repeat the operation, and connect the two marks with a fine, light line. This will be a *Y*-line passing through the point. In a similar manner determine the *X*-line passing through the point. The intersection of these lines is the desired point. If the plotted point is to be used a number of times, the intersection of the lines is pricked with a fine needle to prevent erasure, and the lines in the vicinity of the point are accentuated with a soft pencil. These accentuations do not extend to the point.

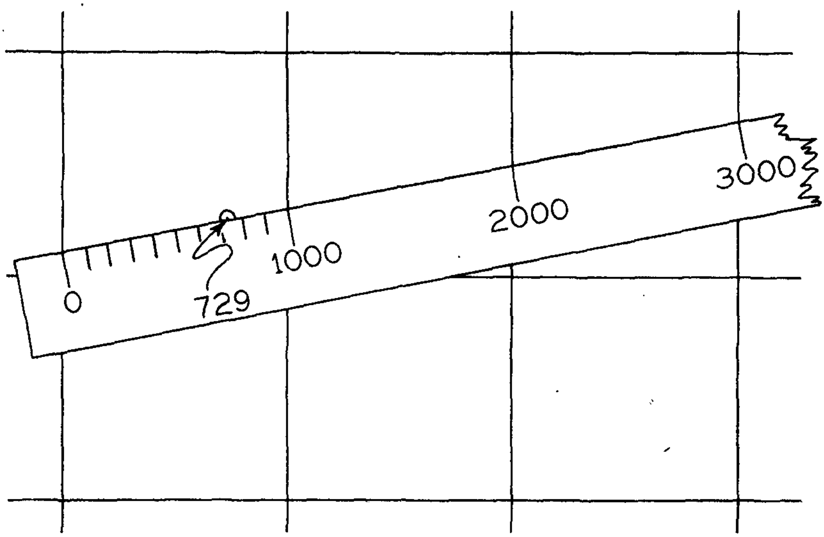


Figure 55. Plotting a point from coordinates when grid lines are closer than normal.

b. Grid lines closer than normal. (See fig. 55.) Plot the point as before, inclining the scale so that zero is on one grid line and the 1000-yard point is on the other. The point then will be plotted in its true relation to the grid, as the digits after the decimal point express the proportional part of the distance between grid lines.

c. Grid lines more distant than normal. (See fig. 56.) Measure the distance between the grid lines and find the difference from normal. The proportional part of this difference is added to a measurement.

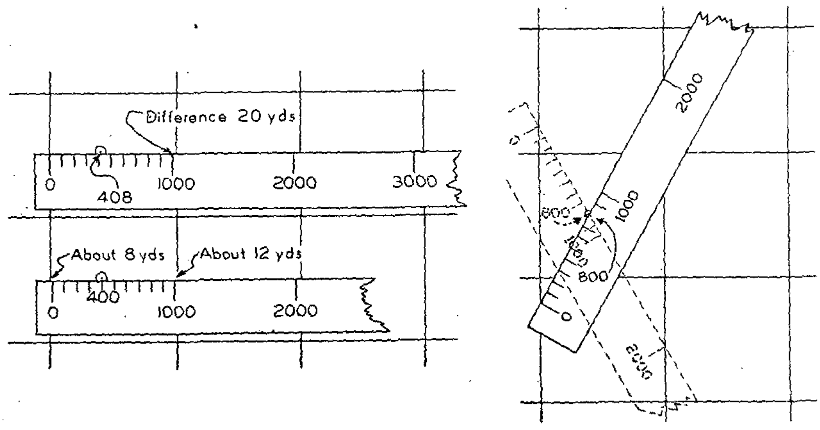


Figure 56. Two methods of plotting points from coordinates when grid lines are more distant than normal. In method b, the scale should be reversed to check accuracy of first plot.

For example, if the distance between grids measures 1020, the difference from normal is 20 yards, and the proportional part of this difference for a 400-yard measurement is 400/1000 of 20, or 8 yards. The 400-yard measurement is scaled as 408 yards. Similar results can be obtained by inclining the scale so that zero is on one grid line and the 2000-yard point is on the other. The yards to be plotted are multiplied by 2, and that distance scaled. In the above example, in plotting the *X*-coordinate, the 400-yard measurement would be scaled as 800 on the inclined scale.

184. MEASURING THE COORDINATES OF A POINT. Coordinates are measured in the same manner as they are plotted except that the distance is read directly between the point and the grid line. Write the number shown at the top or bottom of the *Y*-line west of the point; place a decimal point, and write the distance of the point from this *Y*-line. Place a dash, then the number shown at the right or left end of the *X*-line below the point; place a decimal point and then write the distance of the point from this line. Inclose the whole in parenthesis. If abbreviated coordinates are desired, make the measurements to the nearest 10 or 100 yards, depending upon the approximation desired. If the grid lines are not standard distances apart, the measurements are made as in plotting points.

185. USE OF THE COORDINATE SCALE. The method of plotting described in paragraph 183 is the accurate method used for survey and

for the plotting of target locations for prearranged (schedule) fires. However, it is rather slow when the rapid massing of fires on targets of opportunity or on transient targets is necessary. With a coordinate scale, such as shown in figure 57, targets may be plotted more quickly and with sufficient accuracy. The scale should be so placed that its horizontal scale is in coincidence with a grid line. When the coordinate scale is used in designating or in plotting targets, no attempt should be made to correct for grid lines that are closer together or farther apart than is normal, since the targets will usually be area targets.

To determine the coordinates of a point (fig. 57), the intersecting grid lines forming the lower left hand corner of the grid square in which the point is located are first indicated; then the two numerical coordinates are read to the right and up, in that order, in the same manner as for the fire control grid.

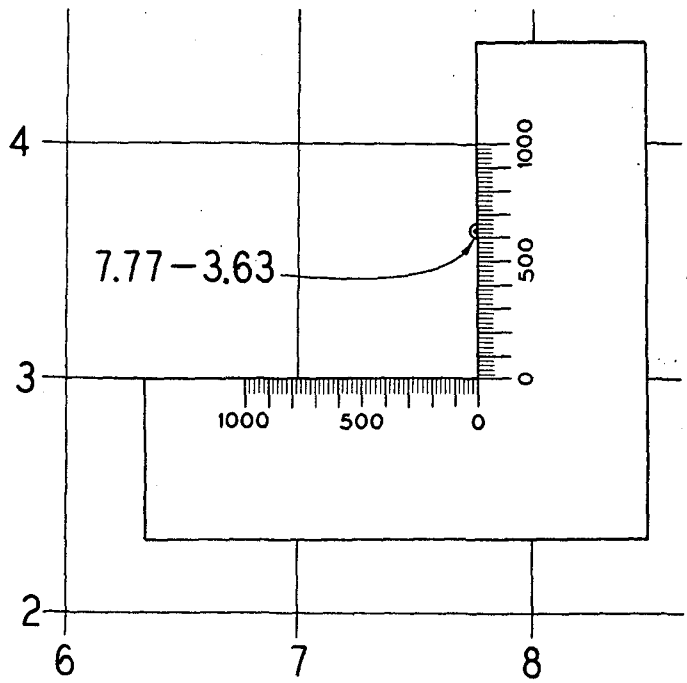


Figure 57. Method of using the coordinate scale.

186. MEASURING AND PLOTTING ANGLES WITH A PROTRACTOR.

a. General. The center of the protractor must be placed exactly over the vertex of the angle, and the base exactly over one side of the angle. For greater accuracy, measure the angle from both sides of the

protractor and take the mean of the readings. For example, measure first with the arc to the right of the center; then with the arc to the left of the center. The difference, if any, between the reading will be small. The mean of the readings is used.

b. Measurement of a *Y*-azimuth.

(1) ORIENTING THE PROTRACTOR FROM A *Y*-LINE. (See fig. 58a.) The *Y*-azimuth of a line can be measured by using its intersection with a *Y*-line as the vertex. The protractor is placed so that the clockwise angle, *Y*-line to given line, is read. If the *Y*-azimuth is greater than 3200, the proper relation of the measured angle to 3200 or 6400 must be determined.

(2) ORIENTING THE PROTRACTOR FROM AN *X*-LINE. (See fig. 58b.) The *Y*-azimuth may also be measured by using the intersection of the line with an *X*-line. Place the center of the protractor over the intersection, and the 1600-mil graduation of the protractor on the *X*-line; the reading of the line is the *Y*-azimuth. If the *Y*-azimuth is greater than 3200 mils, the proper relation of the measured angle to 3200 or 6400 must be determined.

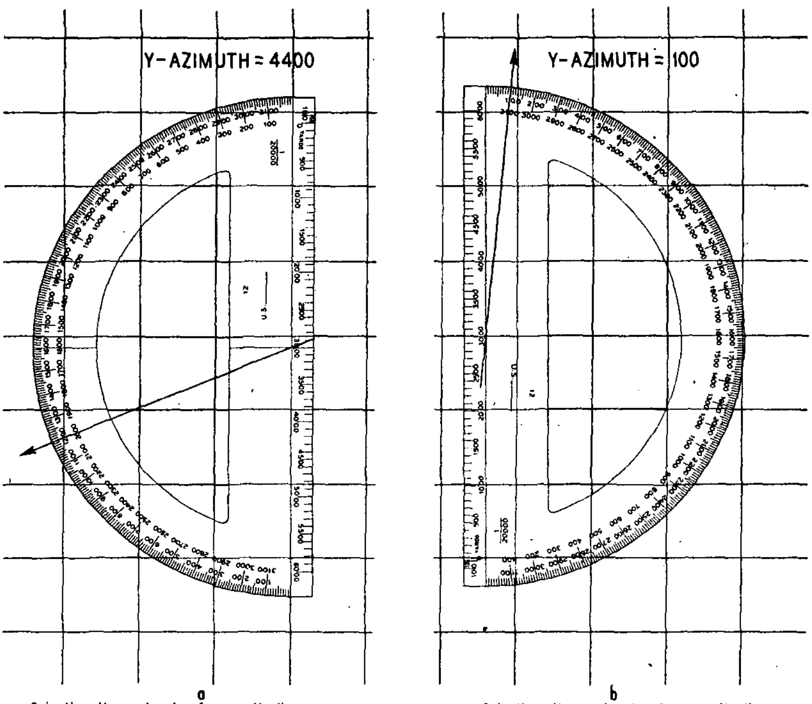


Figure 58. Method of measuring Y-azimuth with a protractor.

c. To draw a line of given azimuth through a point. If the point is on either an *X*-line or a *Y*-line, the line is drawn in the same manner as described above for measurement of *Y*-azimuth. If the point is not on a grid line, the line may be drawn in *either* of the following ways:

(1) (See fig. 59.) The protractor is placed with its center exactly over the point, and the base (straight edge) of the protractor roughly parallel to either an *X* or *Y* grid line. Rotate the protractor about the point until an *X*-line (*Y*-line) cuts off the same length of arc on both ends of the protractor. (In figure 59, the X-line cuts 165 mils of arc from each end of the protractor.) The base of the protractor is now parallel to the *X*-lines (*Y*-lines). A line of given azimuth (or back azimuth) is drawn by marking a point at the circumference of the protractor and drawing a line through the given point and the marked point. In figure 59, the line drawn has a *Y*-azimuth of 5635. Care must be taken to add or subtract multiples of 1600, depending on the quadrant of the azimuth in question.

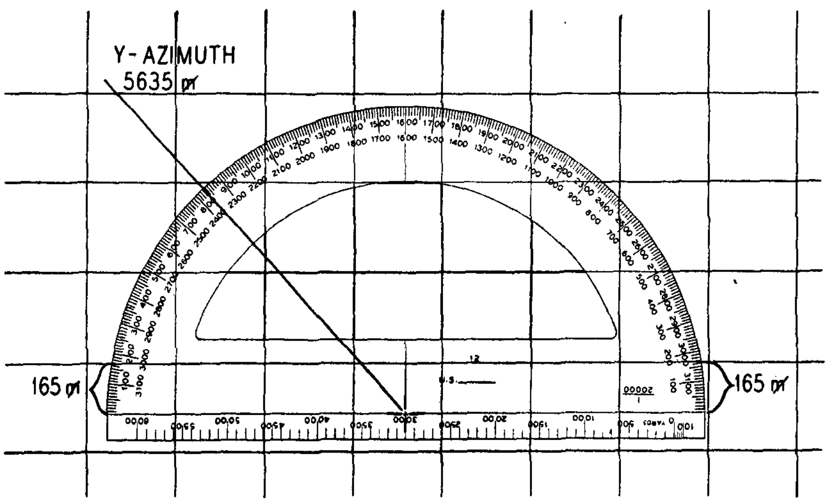


Figure 59. Method of drawing line of given Y-azimuth through a point.

(2) (See fig. 60.) The protractor is placed with its center over a grid line adjacent to the point. The protractor is then revolved until the grid line passes through the angle giving the desired azimuth. The protractor is held in this position and moved along the grid line until the straight edge of the protractor passes through the point. The line of desired azimuth is drawn by marking a point at the straight edge of the protractor and drawing a line through the marked point and the given point.

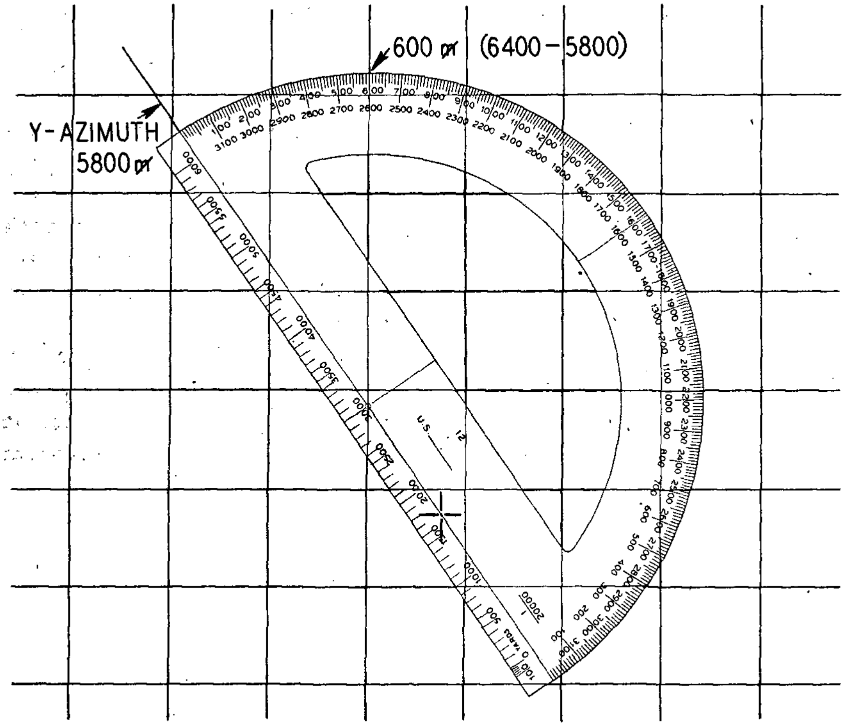


Figure 60. Alternate method of drawing line of given Y-azimuth through a point.

187. MEASURING AND PLOTTING DISTANCES WITH THE PLOTTING SCALE.

a. Measuring. The most accurate method of measuring distances is with the plotting scale.

b. Plotting.

(1) After the direction of a line has been established on the chart (par. 186) its length may be plotted with the plotting scale.

(2) A more accurate method of plotting a definite line for distance and direction is to plot its extremities, using coordinates. Frequently the coordinates of the ends of a line will be too close together to provide a good base for drawing the line. In order to get points that are more widely separated but on the same line, determine the differences in the X and Y coordinates of the two points, multiply these differences by the same figure, and apply the products to the coordinates of the first point—the result is the coordinates of a third point which, when plotted, will lie on an extension of the line between the first two points. Example (fig. 61): the coordinates of point M are (860.200-

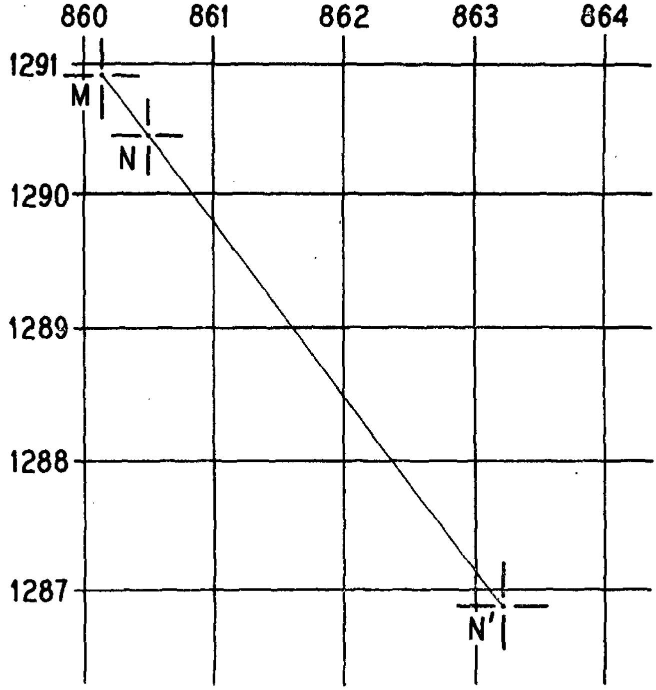


Figure 61. Method of plotting a line by coordinates.

1290.900), and the coordinates of point N are (860.500-1290.500). It is desired to plot the line MN. The points when plotted are too close together to allow a line to be drawn between them satisfactorily. To get points that are more widely separated the procedure outlined above is followed:

Coordinates Point N	=	860.500—	1290.500
Coordinates Point M	=	860.200—	1290.900
Dx	=	+.300	
Dy	=		—.400
Multiply by same figure		10	10
		+3.000	—4.000
Apply to Point M		860.200	1290.900
Coordinates N′	=	863.200—	1286.900

The point N′ is plotted and the line MN′ is drawn. MN′ has the same direction as MN.

188. MEASURING AND PLOTTING ANGLES AND DISTANCES WITH THE RANGE-DEFLECTION FAN.

a. General.

(1) When several angles and distances are to be plotted or measured using one point and one line of direction (and when great accuracy is not necessary), the procedure is greatly facilitated by the use of the range-deflection fan. The range-deflection fan is of particular value in the fire-direction center for use in determining deflection shifts and ranges, and for plotting targets. The range-deflection fan usually has three scales for measuring horizontal angles, each scale capable of measuring angles up to 500 mils. The space available on the firing chart will govern the selection of the scale to be used. If more than one scale falls on the chart, the scale most distant from the vertex should be used. The vertex of the fan is always placed against a pin in the point of origin. The pin should be slightly inclined toward the direction of measurement.

(2) All scales of the range-deflection fan should be checked with scales known to be accurate. Fans with inaccurate scales should be replaced; however, small errors may be corrected or, for short periods of time, compensated for by means of a *K*. Subsequently, the charts or maps upon which the fan is used should be checked from time to time with the fan. For example: originally the distance between two points on the firing chart scales 6620 yards; later, due to stretch, the distance between the same two points measures 6680 yards. Corrections for the charts may be determined by periodically testing the maps in both directions. This procedure is particularly applicable to the firing charts of long range artillery.

b. Measuring. (See fig. 62.) Assume that three points, A, B, and C, have been plotted on the chart. It is desired to measure the distance from A to C and the angle between the lines AB and AC. With the vertex of the fan at A and one side running through B, a fine line is drawn along that side of the fan. The line should extend from approximately 1 inch short of to 1 inch beyond the selected deflection scale. An inverted arrow is placed on this line 1/8 inch beyond the selected scale. With the edge of the fan against a pin in C, the distance AC is read opposite the pin (8100) and the angle is read on the deflection scale opposite the arrow (240 ₥). The normal use of the range-deflection fan is measurement of shifts. In the example above, the shift from B to C, vertex at A, is left 240. (Note that the left side of the fan is against the pin in C. For a left shift the left side is always against the pin for a right shift, the right side.)

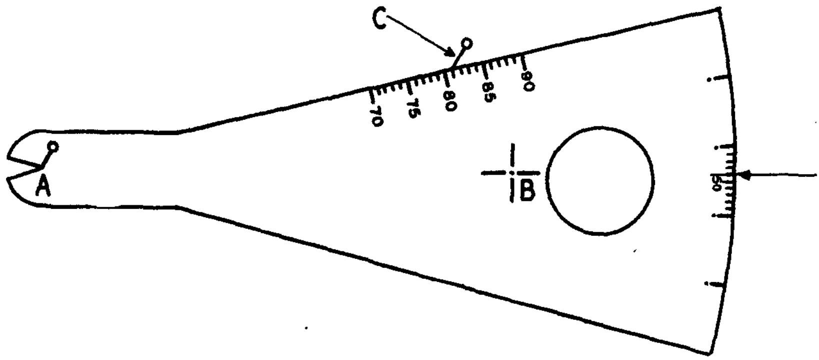


Figure 62. Method of measuring or plotting a distance and an angle with the range-deflection fan.

c. Plotting. (See fig. 62.) The procedure for plotting an angle and a distance is very similar to that used for measuring an angle. Assume in the situation above that points A and B have been plotted on the chart. It is desired to plot C 240 mils left of the AB line at a distance of 8100 yards from A. An extension of the AB line is made as described above. The fan, with vertex at A, is moved until the extension of AB cuts the fan at 240 mils right of the left edge. With the fan in this position, C is plotted at the left edge of the fan at a distance of 8100 yards.

Section II. POINT DESIGNATION GRID, POLAR COORDINATES, AND POLAR PLOTTING

189. POINT DESIGNATION GRID.

a. The printing of accurate fire control grids on photomaps is impracticable because of distortion and the difficulty of reproducing a photo to a desired scale. Therefore, an arbitrary grid, known as the point designation grid, is usually used. This grid has no relation to the actual scale or orientation of the photo; it serves only for point or target designation and normally is not suitable for measurement of distance or azimuth. If the 1/20,000 scale is to be used for determining and plotting the coordinates of points, a point designation grid of 1.8-inch grid squares is the most convenient. Depending upon the scales that are current, other dimensions for the grid squares may be more desirable; for example: for a scale of 1/25,000 graduated in

yards, use 1.44-inch grid squares, and for a scale of 1/25,000 graduated in meters, use 1.575-inch grid squares.

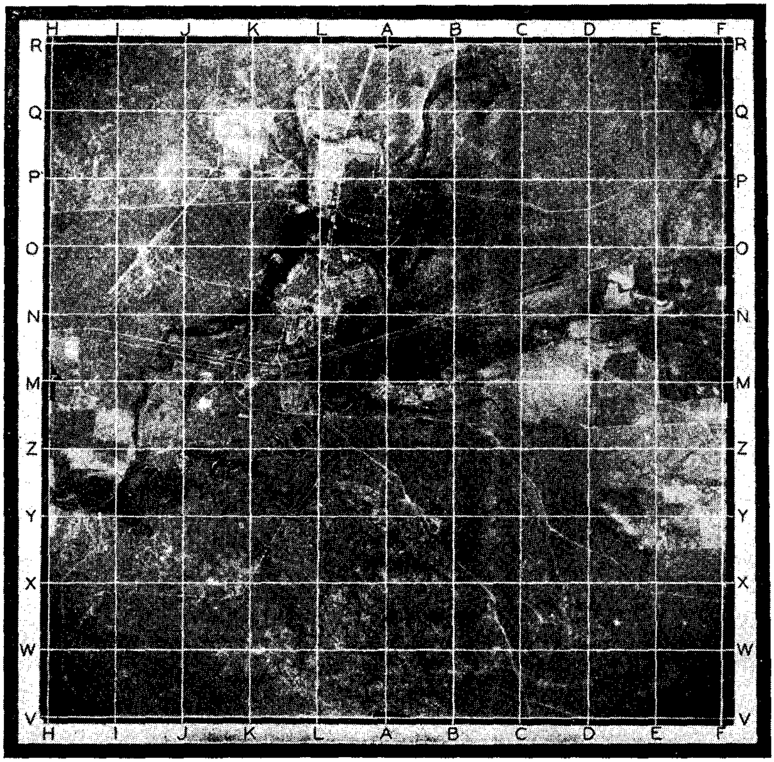


Figure 63. Wide angle photo with point designation grid. Note collimation ticks.

b. The point designation grid may be printed on the photo (as is the case with the wide angle photo, figure 63). For ungridded photos, a transparent template with the grid printed on it may be used; it is essential that all who use this procedure place their templates in ex actly the same position on the photo.

c. The coordinate scale (fig. 64) is always used to plot points or to measure coordinates on a chart having a point designation grid.

190. POLAR COORDINATES AND POLAR PLOTTING. Points may be designated by an angular measurement from a determined direction and a distance from a known point. The angular measurement and distance are known as polar coordinates. The angular measurement may be made from *Y*-north or clockwise from a line fixed by two

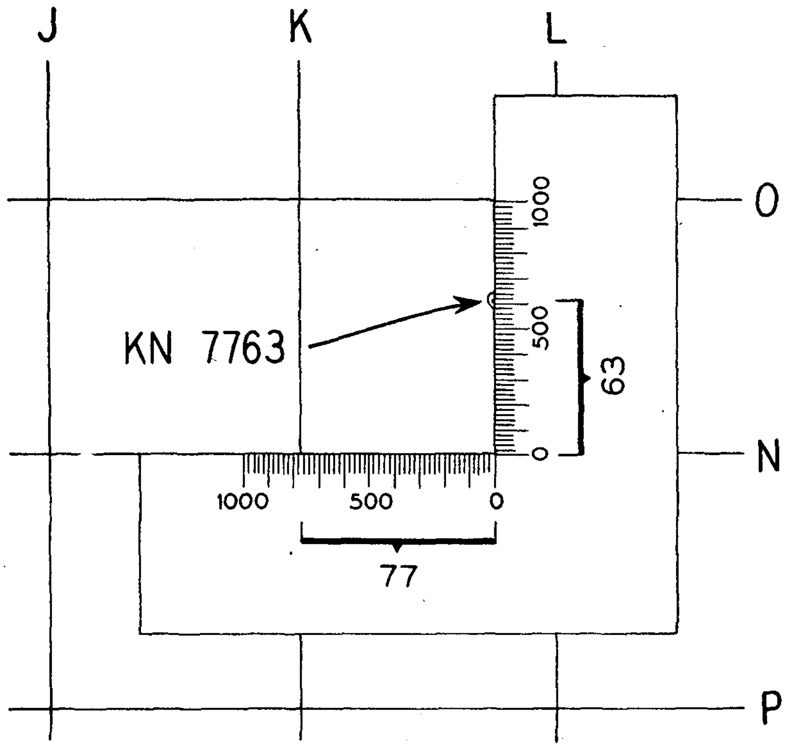


Figure 64. Method of reading coordinates with coordinate scale. The point indicated may be read KN 86 or KN 7763, according to degree of accuracy sought.

known points. The distance may be measured with any predesignated scale. If the distance is measured with one scale and plotted with another, the conversion is accomplished as outlined in paragraph 196. The point of origin, the direction from which to measure the angle, and the scale to be used must be prearranged. The procedure of plotting a point from polar coordinates is known as polar plotting.

CHAPTER 3
AERIAL PHOTOGRAPHS

Section I. VERTICAL PHOTOGRAPHS

191. GENERAL.

a. Air photos furnished to the field artillery will be reproductions of either individual verticals or obliques, or of mosaics assembled from individual wide angle verticals. Air photos are of great value to the field artillery in reconnaissance and in locating and designating targets. In some cases, air photos may also be used as firing charts. When a map or a grid sheet is used as the firing chart, air photos are used to supplement them for horizontal and vertical locations.

b. See FM 21–26 for interpretation of air photos.

192. WIDE ANGLE VERTICAL. The wide angle vertical is an air photo taken with the camera plate as nearly horizontal as practicable. The wide angle camera has a 6-inch focal length and an angle of view of approximately 70 degrees across the square dimension of the photo and approximately 90 degrees across the diagonal. Wide angle verticals normally are taken in a series of overlapping photos.

193. TILT AND RELIEF.

a. General. If a flat piece of terrain is photographed vertically, the result is a map that is perfect in all planimetric detail (fig. 65). However, the vertical air photo is subject to distortion of detail due principally to tilt of the camera and to relief of the terrain photographed.

b. Tilt. If the camera is not level at the moment the photo is taken, the scale of the photo will not be uniform. In figure 66, it is evident that a horizontal line of a certain length near A will appear longer on the photo than a line of the same length near B, since A is nearer the camera than B. When the tilt is small, as is the case in a carefully made photo, the resulting errors are negligible for artillery work. In a series of overlapping photos taken on a single flight, excessive tilt of one photo is apparent if its center is materially out of plaçe with reference to the line of centers established by the other photos. Field artillery

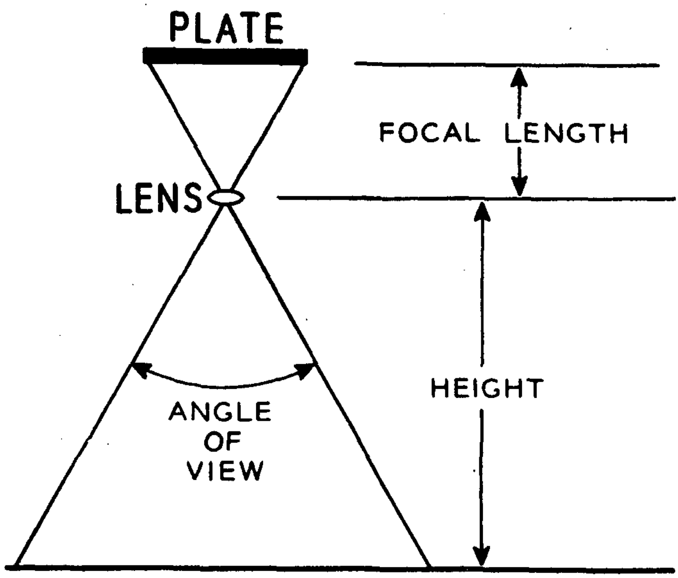


Figure 65. Relation of photo to ground.

units are not equipped to remove tilt from photos. If tilt is large enough to distort the photo materially, the photo will be almost useless for survey purposes.

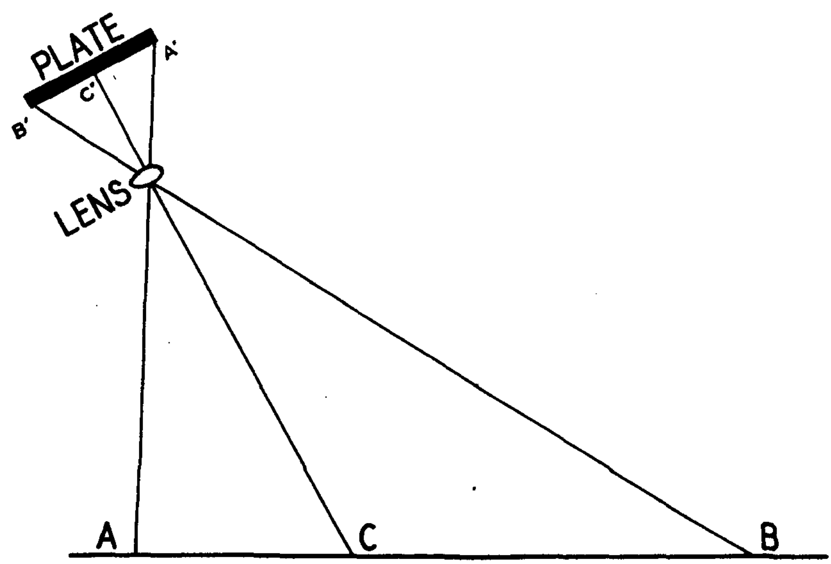


Figure 66. Effect of tilt.

c. Relief. The second important source of error is relief. Considering figure 67a as any vertical section through the axis of the lens, it is seen that C will be recorded in its true position, the center of the photo, regardless of its altitude. With reference to a horizontal datum plane MN, the object A at a greater altitude will record as an object located at A′; similarly B will record as at B′. These displacements are radial from or towards the center, as shown in figure 67b. For a given altitude of the airplane, the amount of displacement varies directly as the horizontal distance from C and the height above or below C. Note that directions of the radial lines, CA and CB, are not changed by the displacements of A and B. The relief distortion of any particular point varies inversely as the altitude of the airplane. The amount of distortion can be found by solving the following proportion (fig. 68):

$d/D = h/H$ where d = displacement correction in yards radially toward (from) center of photo.

h = height in feet of ground above (below) ground at center of photo.

D = distance in yards from center of photo to point to be corrected.

H = height in feet of camera lens above center of photo (altitude of airplane). Since it usually is not practicable to determine the altitude of the center of the photo, an altitude, usually that of the center of the target area, is assigned as

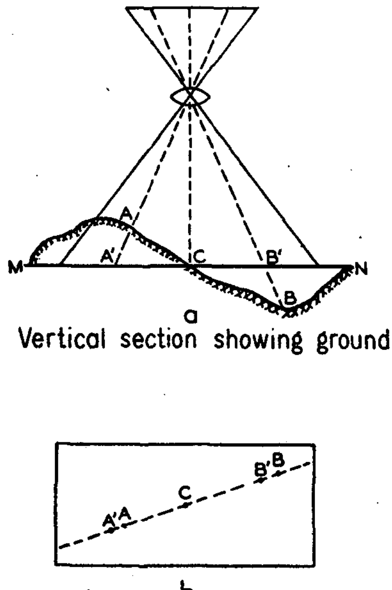


Figure 67. Displacement due to relief of ground.

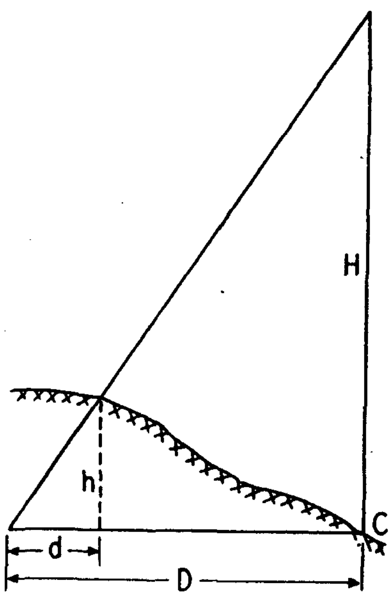


Figure 68. Determination of relief distortion.

the mean datum plane and used as the basis for determining distortion corrections.

d. Example. (See fig. 69.) An air photo taken at an altitude of 25,000 feet is to be used as the battalion firing chart. The base point has been assigned an arbitrary altitude and is to be used as the mean datum plane. By survey, point A has been determined to be 180 feet above the base point. The distance from point A to the center of the photo is scaled as 4000 yards.

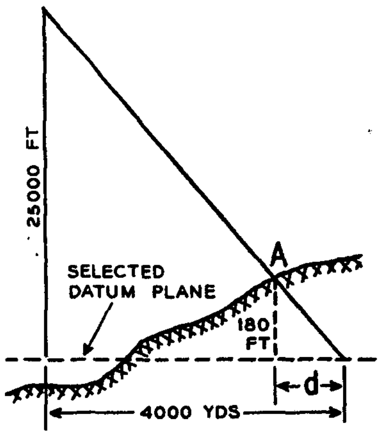


Figure 69. Example of correction for relief distortion.

$$\frac{d}{4000} = \frac{180}{25{,}000}$$

$d = 28.8$ or 29 yards. Point A will be plotted 29 yards toward the center of the photo from its photo location.

194. DIRECTION IN PHOTOS. The effect of relief is the displacement of images radially from or toward the center of the photo. The effects are shown in figure 70. The points a and b are on higher ground and the point d is on lower ground than the center of the photo. In the figure, a, b, and d represent the true locations of these points, whereas a′, b′, and d′ represent the photo locations. The lines a′d and a′b′ are not true direction lines, whereas ca′, cb′, and cd′ are true, and b′d′ is approximately true. It follows that the directions of lines passing through or near the center of an average vertical photo are substantially true. However, lines passing well away from the cen-

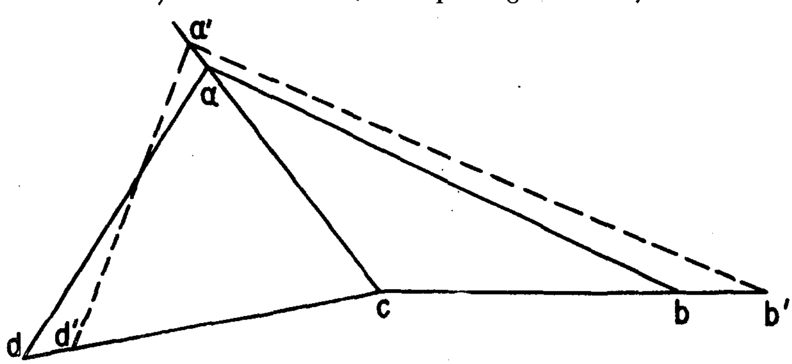


Figure 70. Effect of relief displacement on direction and scale.

ter and joining points of different altitudes whose images lie in the outer field of the photo may show excessive errors when the relief is considerable. If the altitude from which the photo was taken is known, the error may be corrected by a replot of the points to the same datum plane (par. 193c).

195. DETERMINING SCALE OF PHOTOS.

a. From figure 65, it is evident that the approximate scale of the photo can be expressed by the formula: RF (representative fraction) = focal length divided by height. Hence the scale of the photo and the area covered by the photo depend upon the focal length and the height. For example, if a 7-inch $\times$ 9-inch photo is taken at a height of 20,000 feet with a camera of 6-inch focal length, the scale is .5/20,000 or 1/40,000, and the area covered is $(7 \times 40{,}000) \times (9 \times 40{,}000)$ inches, or about $8000 \times 10{,}000$ yards.

b. The scale of the photo as determined above is unsatisfactory. It may be inaccurate for any of the following reasons:

(1) Because the altimeter may not have been set accurately at zero for the area photographed.

(2) Because of barometric variations which affected the altimeter.

(3) Because of shrinkage of negative and print.

c. (1) The basic method of determining the scale of a photo is to determine the relation between a photo distance and the corresponding ground distance. For example, the photo distance between two points is 5.40 inches and the ground distance between the same two points is 3100 yards (111,600 inches). The scale is determined by solving the equation $5.40 : 111{,}600 = 1 : x$. From the equation, $x = 20{,}667$, and the scale is 1/20,667.

(2) The points between which the distance is measured should be selected carefully. They should be well defined both on the photo and on the ground; they should be far apart and near the average ground level, so as not to introduce material error through distortion. In flat terrain, points separated by 2000 yards are satisfactory. In general, the greater the distance between the points, the more accurate is the scale. They should be approximately equidistant from the center of the photo and chosen so that the line joining them passes near the center of the photo. A more accurate value of the scale of the photo can be determined by averaging the scales determined by two such lines roughly perpendicular to each other.

(3) Figure 70 shows the effect of relief distortion on the scale. The lengths of the radial lines ca′, cb′, and cd′ are not accurate for the datum plane through c. Points a and b have been moved outward and point d inward by relief distortion; thus, for the datum plane

through c, the lengths ca′ and cb′ are too great, and the length cd is too small. To construct an accurate chart for the datum plane through c, a′, b′, and d′ should be replotted (fig. 70) at a, b, and d respectively (par. 193). Except in comparatively flat terrain, it is necessary to consider the possibility of relief distortion when selecting points.

(4) When determining the scale of a wide angle photo taken from a known altitude, it is desirable to select points of about the same altitude, or, if the altitudes differ materially, to replot one or both points to a selected datum plane. In case the points have the same altitude, the scale is determined for the datum plane of these points; for example, 1/20,300 at 1600 (feet altitude). If the locations of the points have been replotted to a selected datum plane, the scale determined is the scale for the selected datum plane.

(5) A scale determined by using one point in the target area and the other in or near the position area usually gives the best results because, while the scale obtained may not be the best for the photo as a whole, it is relatively the most accurate for distances from the position area to the target area.

196. CONVERTING PHOTO AND TRUE MEASUREMENTS.

Photo measurements may be converted to true measurements (and true to photo) as follows:

a. By relation to any convenient scale. For example, the true ground distance between any two points identified on a photo has been determined to be 1500 yards. Using any convenient plotting scale, the distance between the same two points on the photo measures 1800 units. This relation is shown by the following equation:

$$\frac{\text{Photo measurement}}{\text{True measurement}} = \frac{1800}{1500}$$

Using the above equation, the conversion of photo measurements to true distances (and the reverse) may be accomplished quickly and accurately with a slide rule by setting the photo distance on the C scale over the true distance on the D scale (fig. 71). Using the measurements given above, the reading of 1800 on the C scale is placed over the reading of 1500 on the D scale to set the rule for conversion. To convert a photo measurement of 2100 units to true distance, locate 2100 on the C scale and the true distance, 1750, will appear directly below it on the D scale.

b. By use of the graphical firing table. When a photo is used as a firing chart, the conversion of photo measurements to firing data is accomplished automatically by use of the graphical firing table.

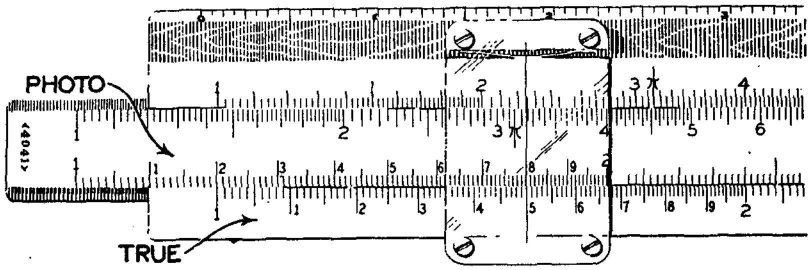


Figure 71. Method of using slide rule for conversion of photo measurements to true distances.

197. TYPES OF MOSAICS. An uncontrolled mosaic is compiled by any one of several techniques involving matching of detail. A controlled mosaic is compiled by fitting the images of control points over their locations plotted on a control sheet; sometimes the prints must be rephotographed to bring them to the average scale, or must be rectified if they are appreciably tilted.

198. ASSEMBLY OF MOSAICS.

a. General. Normally, mosaics will be assembled and reproduced by the engineers, and the reproductions distributed to the field artillery. Situations may arise, however, when it will be necessary for field artillery to assemble their own mosaics. Whenever possible, this assembly should be made by the radial line method described in TM 5–230, since this gives the most accurate results. A somewhat simpler method which gives fair results appears below. This method is applicable when the overlap is less than the 60 per cent required for the radial line assembly method.

b. Assembly of strip mosaic. The first step in assembling a mosaic is to assemble two photos as a strip. Any two overlapping photos may be used.

(1) Locate the photo centers from marginal information (collimation marks). (Centers may also be located by the intersection of the two diagonals.)

(2) Secure one photo to the board on which the mosaic is to be assembled.

(3) Orient the second photo relative to the first by matching detail.

(4) Draw a line joining the two centers, C–1 and C–2, and extend it across that portion of photo 1 which was overlapped by photo 2 (fig. 72). This line is the approximate common radial line of the two photos. The purpose of determining such a radial line is to permit the selection of two suitable orientation points on or near this line that

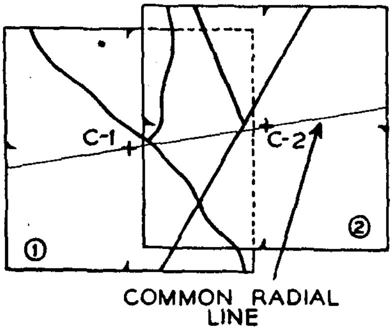


Figure 72. Method of determining common radial line.

are identifiable on both photos. The reason for using points along a common radial line is that if the points are distorted they will be distorted along the common radial line, and the direction of a line established by the two points will not be affected materially by the distortion. If there is sufficient overlap, the actual centers are used.

(5) The two points selected should be as near as possible to the radial line, on the same side of the radial line, and as far apart as possible. In figure 73, two points would be a and b, labeled a_1, b_1, and a_2, b_2 on photos 1 and 2 respectively.

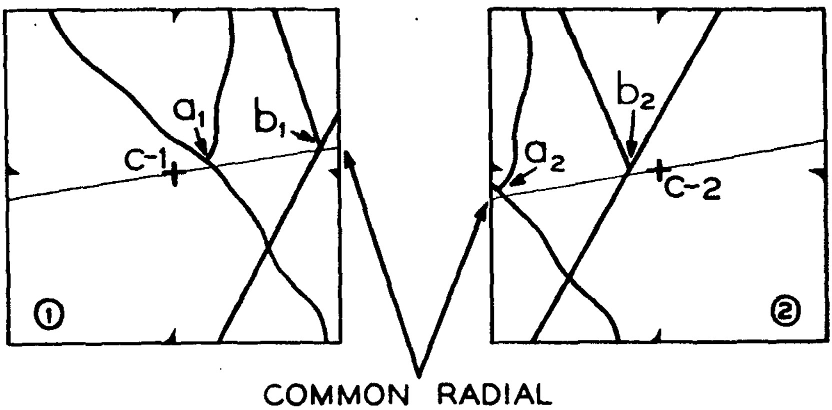


Figure 73. Selection of orientation points.

(6) Draw the line a_1 b_1 on photo 1, extending it on to the board (fig. 74). Draw the line a_2 b_2 on photo 2, extending it to the edges of the photo.

(7) On photo 1 determine the mid point between a_1 and b_1 and mark it on the photo. On photo 2 determine and mark the mid-point between a_2 and b_2. Place photo 2 over photo 1 so that the mid-point of a_2 b_2 is over the mid-point of a_1 b_1, and the line a_2 b_2 coincides with the extension of a_1 b_1 on the board (fig. 75). The photos are now oriented and located. Photo 2 is secured to the chart. Additional photos may be added in the same manner if only a strip mosaic is to be assembled.

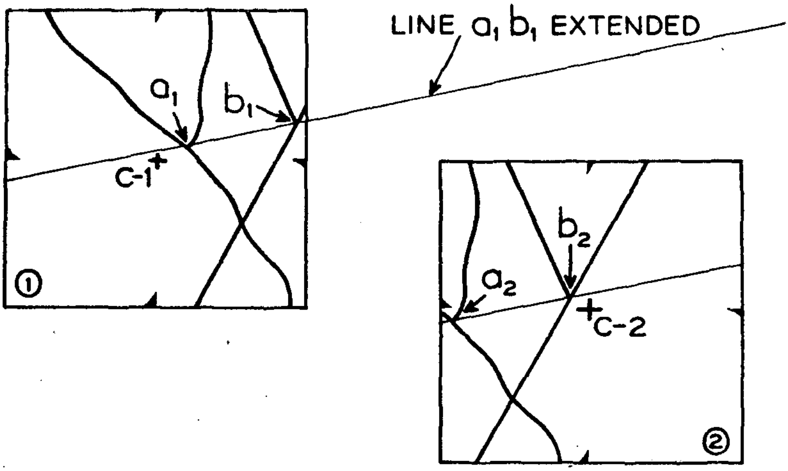


Figure 74. Orientation points on both photos connected by lines.

c. Assembly of area mosaic. If the mosaic is to be an area mosaic rather than a strip mosaic, the procedure after assembly of the first two photos is as follows:

(1) Determine the center of photo 3.

(2) Orient photo 3 by matching detail with photos 1 and 2.

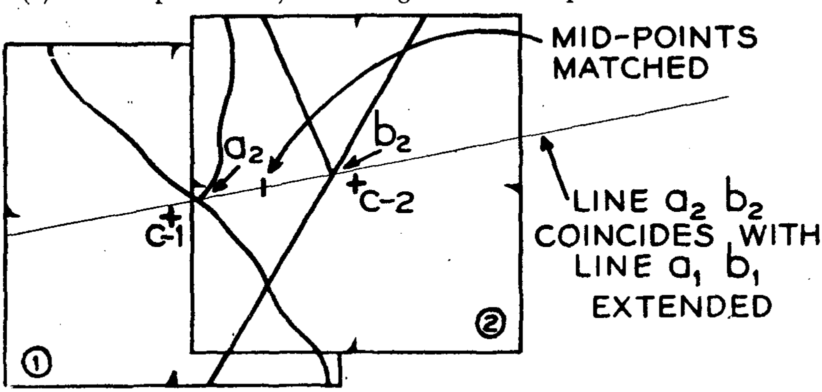


Figure 75. Photos oriented and located by bringing the lines into coincidence and matching the mid-points.

(3) Draw lines joining the center of photos 3 with the centers of photos 1 and 2. These lines are approximate common radial lines to be used in selection of orientation points.

(4) Select two points on photo 3 that can be identifed on photo 1. The factors controlling the selection of these points are identical with the factors that controlled the selection of the orientation points for assembly of photos 1 and 2. In figure 76, the points are d and e,

labeled d_1, e_1, and d_3, e_3 on photos 1 and 3 respectively. In the same manner, select two points on photo 3 that appear on photo 2. In figure 76, these points are f and g, labeled f_2, g_2 and f_3, g_3 on photos 2 and 3 respectively. Frequently, it will be necessary to raise one photo slightly in order to find desired points that are covered by overlap; this procedure is more advisable than trimming away part of the photo before it has been ascertained exactly where the trim line will fall.

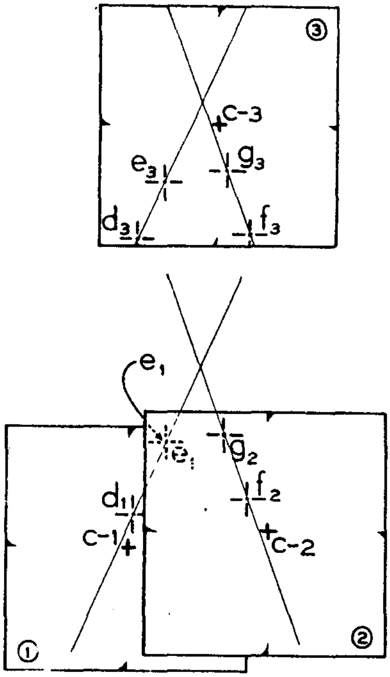


Figure 76. Selection of orientation points on three photos and connection of points by lines.

(5) Draw lines d_1 e_1 (fig. 76) and f_2 g_2, extending them across photos 1 and 2 and well past their point of intersection. Draw lines d_3 e_3 and f_3 g_3 entirely across photo 3.

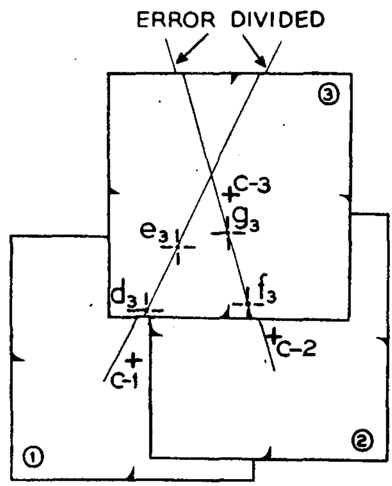


Figure 77. Three photos oriented by matching points of intersection and bringing the lines into coincidence.

(6) Place the intersection of d_3 e_3 and f_3 g_3 on photo 3 over the intersection of d_1 e_1 and f_2 g_2 (fig. 77). Orient photo 3 on photos 1 and 2 by causing lines d_3 e_3 and f_3 g_3 to coincide with lines d_1 e_1 and f_2 g_2 respectively. If perfect coincidence is not obtained, the error is divided. Photo 3 is fastened to the board.

(7) Additional photos may be assembled in the same manner as photo 3.

d. When the entire mosaic has been assembled, the excess of each photo is trimmed away in such a manner as to preserve as much of the center of each photo as is possible.

199. RESTITUTION.

a. General. Restitution is the process of determining the map or chart locations of features appearing on air photos. The methods discussed in this section apply to vertical air photos. The basic principle of accurate restitution is the assumption that all angles measured at the center (principal point) of a given photo with less than 3 degrees of tilt are true angles and that this is the only point on the photo where this is the case. Any method of restitution which makes use of this principle, using overlapping photos (radial line), gives accurate results whereas any method which is based upon other angles or single photos will provide less accuracy, depending upon the amount of relief distortion of the given photo. Section II describes methods of using oblique photos for this purpose.

b. Radial line method.

(1) USE. This method is used to restitute a point appearing in the overlap of two aerial photographs taken at different camera positions when the tilt of the photos (from vertical) is 3 degrees or less.

(2) PROCEDURE.

(*a*) Identify on each photograph three control points whose chart locations are known A different set of points may be selected for each photograph or the same identical points may be used. The points selected should be well out from the center of each photo and so distributed that the rays drawn from them to the photo centers provide good three-ray intersection.

(*b*) Place tracing paper over the firing chart and prick the chart locations of the control points to the tracing paper.

(*c*) Draw rays from the center of each photo to the photo location of the control points.

(*d*) Place the prepared tracing paper over one photo so that the rays (drawn in (*c*) above) on the photo pass through corresponding control points on the tracing paper.

(*e*) Draw a ray on the tracing paper from the photo center to the point to be restituted.

(*f*) Repeat (*d*) and (*e*) above using the second photo and the same tracing paper.

(*g*) Intersection of rays gives the tracing paper location of point to be restituted.

(*h*) Orient tracing paper over firing chart and transfer point to be restituted to the chart.

(3) For a detailed discussion of the radial line method, see TM 5–230.

c. Fire control data sheet.

(1) GENERAL. Under certain conditions when a controlled mosaic is not available, a suitable substitute is furnished in the form of a gridded plot, to an appropriate scale (on the theater grid), of the principal point of each of a number of vertical photos. This plot is usually prepared by the engineers of the higher echelons (army or base section) and provides a means for determining the true coordinates of any point which can be identified on each of two adjacent overlapping verticals. A discussion of how this grid plot is prepared appears in TM 5–230.

(2) USE. The gridded plot in (1) above may be in the form of an acetate sheet on which appears the theater grid with the principal points of the photos of the basic cover plotted in their true location. Any other control points which are available may also be shown. Alternately a list of principal point coordinates may be supplied. Having the grid positions of the photo principal points and knowing that the principal point is *angle true,* it is a simple matter to intersect any desired feature appearing on the photos and thus to obtain its true coordinates. It is a variation of the radial line restitution method described in subparagraph b above.

NOTE: The photos obtained for use with this plot will usually have the course lines on them; if not, this line may be put on as follows:

If the principal point p_2 of photo 2 falls exactly on a piece of detail, then its position on photo 1 can be identified easily and the course line p_1 p_2 drawn as a fine line. Unfortunately, in many cases it will be in the middle of a field or other open space. The procedure in this case is (see fig. 78):

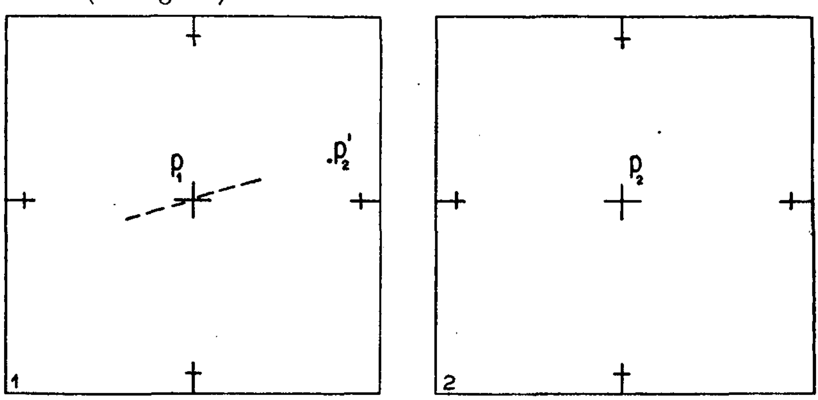


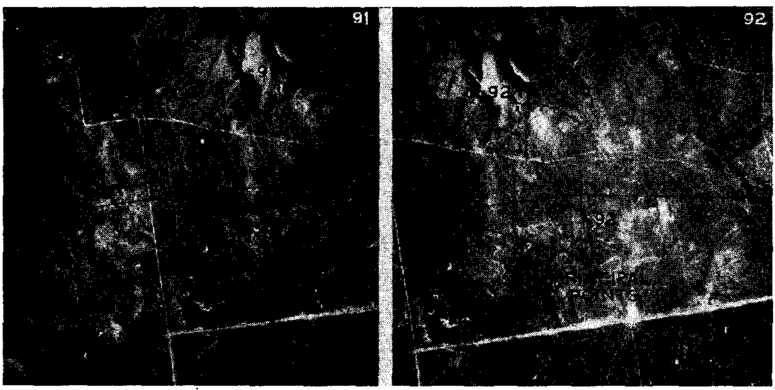
Figure 78. Placing the course line on photos.

(*a*) Identify p_2 approximately on photo 1 at p'_2 and aline a straightedge on this point and principal point p_1.

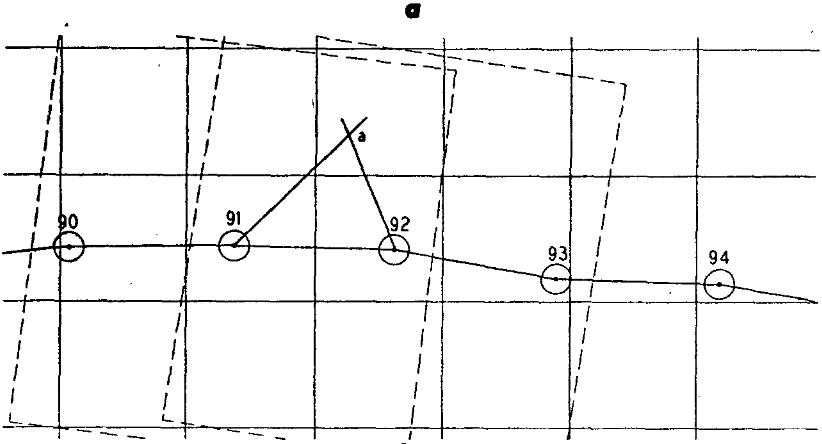
(*b*) Score, with a needle, a small part of the course line at p_1 (shown dotted). A small error at p'_2 would not affect this part of the line.

(*c*) Now, instead of trying to identify principal point p_1 on photo 2, it is easier to select some piece of detail which lies exactly on the short scored line through p_1. Join this selected position to p_2 and the course line of photo 2 is correctly established.

(*d*) The course line of photo 1 is fixed by choosing, in the vicinity of p_2, a point which lies on the course line of photo 2, by identifying it on photo 1, and by joining it to the principal point p_1.



a



b

Figure 79. Method of using fire control data sheet with photos to determine true coordinate of a point: a. Two adjacent overlapping vertical photos; b. Fire control data sheet on acetate with theater grid, showing principal points.

(3) ILLUSTRATIVE EXAMPLES. In order to obtain the map coordinate of a ground point, A, whose image position on photo 91 is a–91 and on 92 is a–92 (fig. 79), the procedure is as follows:

(*a*) *With an acetate grid.* Place photo 91 under the acetate with its principal point (91) directly under the plotted position of this point, and the course line coincident with the plotted course line 91–92. Draw a ray from a–91 to the principal point. Now place photo 92 under the acetate in the same manner in its proper position, and draw a ray from a–92 to the principal point of 92. The intersection of these rays is the map location of point A, and is corrected for nearly all tilt and relief distortion.

(*b*) *With the principal points plotted directly on the firing chart.* If a list of the coordinates of principal points, instead of a gridded plot on acetate, is provided by the engineers of higher echelons (see c (2) above), these points may be plotted directly on the firing chart, and course lines drawn to connect them. Targets may be restituted to the firing chart from photos of the basic coverage by the following method:

1. Place a piece of tracing paper or acetate over the plot on the firing chart and draw the course line 91–92, taking care to mark the principal points accurately so that the distance 91–92 is the same on the plot and on the tracing paper.

2. Orient this tracing over photo 91, 91 of the trace over the principal point of the photo, and the course line of the trace over the photo course line 91–92. With the trace in this position, draw a ray from a–91 to the principal point. Note that the distance 91–92 may differ on each photo, and on the trace.

3. Place the trace on photo 92, 92 of the trace over the principal point of 92, and aline the course line with the photo course line 92–91. Draw ray from a–92 to 92, intersecting the first ray in a.

4. Replace the trace on the firing chart, in the same position as in *1* above, and prick through the position of a.

(*c*) *Points very close to the course line.*

1. If the point to be intersected lies very close to the course line, the intersection of the rays will be at too great an angle for accuracy, and the following procedure must be used:

(i) Such a point is b, figure 79a. On each photo drop a perpendicular bb′ to the course line, as shown.

(ii) On the trace or acetate, figure 80, draw 91–92′ at about 30 degrees to the course line. Mark 91–b′ equal to 91–b′ from photo 91 (fig. 79a), and mark b′–92′ equal to b′–92 of photo 92.

(iii) Join 92′–92, and draw b′b″ parallel to 92′–92, cutting the base in b″. Erect the perpendicular b″b. Now draw either ray 91b or 92b (or both) as before; the intersection of either with the perpendicular establishes b.

2. If the point to be located is on the course line, the same procedure is followed except that no perpendicular is used; b and b′ will coincide on the photos and b″ will be the location of the point on the trace.

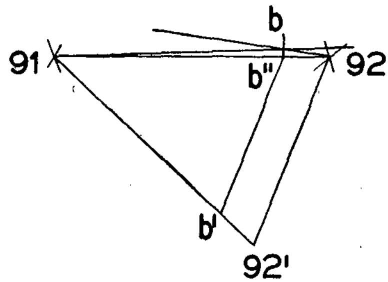


Figure 80. Method of locating a point close to course line.

d. Polar plot method.

(1) USE. This method is used to locate targets when only a single vertical of the area is available or when there is insufficient overlap for radial line restitution. Since the angles used are not radial, inaccuracies from relief and tilt may be introduced.

(2) PROCEDURE. Two or more well separated points whose chart locations are known are identified on the photo. A line is drawn between these two points on both the photo and the chart. The line on the photo is extended so as to enable shifts and distances to be measured from either of the points with a range-deflection fan (par. 188b). The line on the chart is extended so as to enable shifts and distances to be plotted from either of the points with a range-deflection fan (par. 188c). The difference in scale between the photo and the chart is considered by measuring the photo and chart distances and by setting up a relation between the two on the slide rule (par. 196). When a point is to be restituted from the photo to the chart, the photo shift and distance are measured from whichever known point will give the smallest angle and the largest distance. To reduce errors of relief and tilt, the base should be chosen so as to pass close to the center of the photo, and the base ends should be at about the same altitude. The photo distance is converted to chart distance by the use of the established relationship. The desired point is plotted on the chart with the same measured shift and the true distance.

(3) EXAMPLE (fig. 81). The chart location of points A and B, which are identifiable on the photo, have been determined. It is desired to restitute points to the firing chart from the photo. The AB line is drawn on the photo and on the chart and is extended as necessary to allow the range-deflection fan to be used with vertex at either

A or B. The distance between A and B is measured on the photo (assume 4000 yards) and on the chart (assume 5200 yards). The photo-chart relationship is set up on the slide rule by placing 4000 on the C scale over 5200 on the D scale. To transfer point T from the photo to the chart, the fan is placed with its vertex at B on the photo, and the shift from the BA line to T (R 405) and the distance from B to T (3980 yards) are measured. Using the slide rule on which the photo-chart relationship is set up, the photo distance (3980 yards) is converted to chart distance (5150 yards). The fan is then placed with its vertex at B on the chart, and T is plotted 405 mils right of the BA line at a distance of 5150 yards from B. The transferred location of T is in error due to errors in the relative photo location of T with respect to the restitution points. This may be corrected as in paragraph 193c.

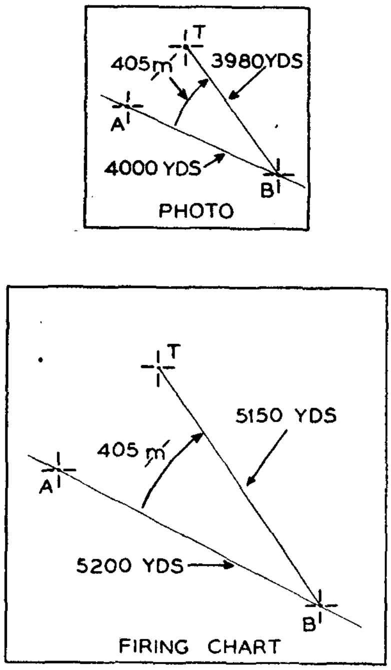


Figure 81. Polar plot method of restitution.

(4) ALTERNATE POLAR PLOT METHOD. In the example above, the transferred location of T would include errors introduced by erroneous photomap locations of the restitution points A and B. A method of restitution, applicable to individual photos, which partially eliminates these errors is as follows:

(*a*) At least three points whose chart locations are known are identified on the photo. The photo center is determined.

(*b*) An overlay is made from the photo showing the three points and the photo center.

(*c*) Using the overlay, the location of the photo center is resected (par. 246b) to the chart.

(*d*) When the photo center has been located on the chart, the procedure for transferring points is the same as in subparagraph d (2) above except all measurements on the photo and all plotting on the chart are performed with the vertex of the fan at the photo center.

200. STEREOSCOPIC COVERAGE. Normal methods of restitution do not include adequate means for determination of vertical control. Stereoscopic coverage augments and aids in the determination of relative altitudes and aids photo interpretation. See FM 21–26.

Section II. OBLIQUE PHOTOGRAPHS

201. GENERAL.

a. The mil-gridded oblique pictures the terrain substantially as it would be seen by an observer through an instrument having a fully graduated reticle and which was located at the point occupied by the camera at the instant the photo was taken (fig. 82). The vertical and horizontal grid lines have graduations with which horizontal and vertical angles may be read; these, in effect, make the mil-gridded oblique another survey instrument. If successive plumb points represent ends of a base, and the gridded photos include a reference point the location of which is known, the principles of long base intersection may be employed to transfer points from mil-gridded obliques to firing charts or maps.

When mil-gridded obliques are used, targets normally are located with such accuracy that fire for effect may be initiated immediately. When fire is placed on the target, if errors occur which are traceable to the obliques only, surveillance of the first mission will permit the determination of a *K* which will compensate for errors in the control and in the plotting from the obliques. Corrections may be improved as subsequent missions are fired.

b. Coordinates and altitudes of plumb points (geographic location of camera at the instant the picture was taken) and reference points will normally be furnished by the corps observation battalion or by division artillery headquarters if the division is operating separately. However, using units should be capable of determining these critical data.

c. Technical information. For details of construction and uses of grids, corrections for tilt and dip, and corrections for misplaced grids, see appendix VI.

202. HORIZONTAL LOCATIONS.

a. Orientation of photographs. Orientation is accomplished by determining the chart locations of plumb points and the chart directions of center lines.

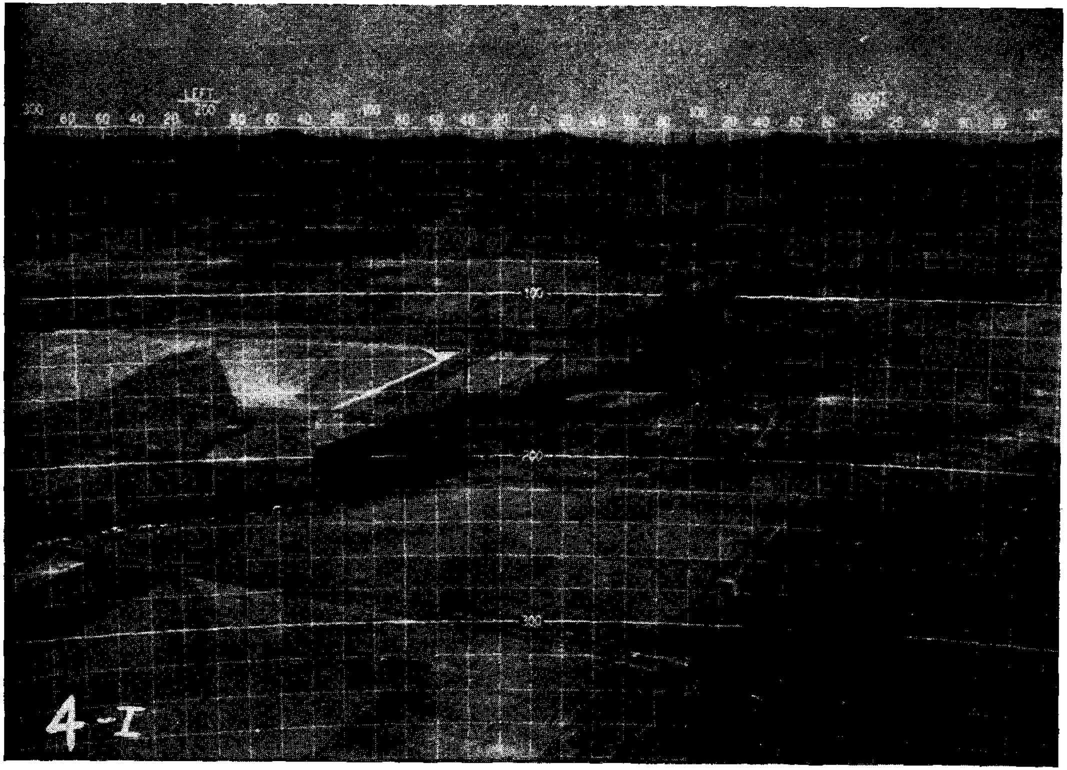
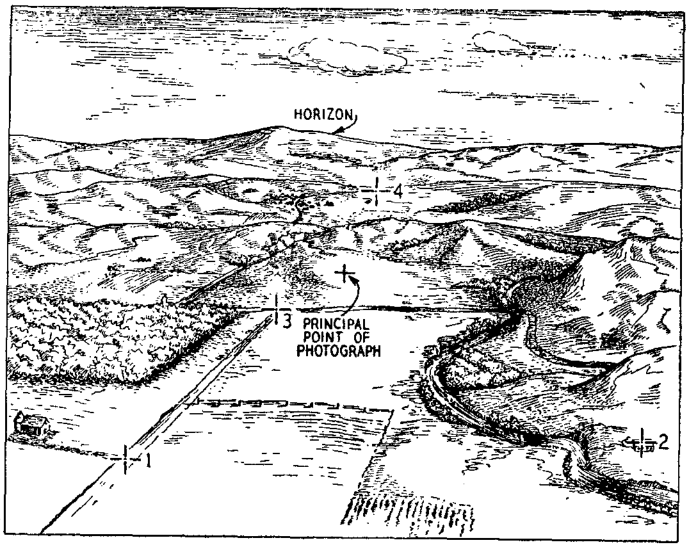


Figure 82. Mil-gridded oblique photo for use in resection.

(1) PLUMB POINTS. The location of the plumb point may be determined by: a vertical photo taken simultaneously with the oblique; intersecting the position of the airplane at the instant the picture is taken; and/or resection. Plumb points of oblique photos taken from observation posts may be located by ordinary survey methods.

(*a*) *Simultaneous vertical and oblique.* Whenever possible, it is desirable to have a vertical photo taken simultaneously with the oblique. If the photo is taken with the optical axis of the camera truly vertical, the center of the picture is the plumb point. If, however, for any reason, the camera deviates from the vertical, corrections, as described in appendix VI, must be applied to locate the plumb point accurately on the vertical photo.

Once the photo location of the plumb point has been determined, its ground location must be identified; normally, this will be easy to do (because of the altitudes at which these photos are taken, verticals of relatively large scale will result). The plumb point is tied to the chart by survey which may consist of only a short traverse if the line of flight was over the position area. Since it is possible to occupy its ground position, this method of locating plumb points gives the great-



POINTS	DISTANCES FROM THE PLUMB POINT
1 and 2	As near as possible and in the corners of the photo.
3	In the middle distance (4000 to 6000 yards).
4	As far away as possible, at least 8000 yards. With poor visibility, 7000 yards minimum.

Figure 83. Selection of control points.

est accuracy. Survey, even for several successive plumb points, need not be a serious problem if control is available at various separated points along the line of flight.

(*b*) *Intersection.* Occasionally, the most feasible method of locating the plumb point will be to triangulate its position by taking simultaneous observations on the airplane, using a base the location of which is known. Communication is necessary. Each observer tracks the airplane in its flight until the instant the picture is taken, at which time the tracking stops and the instrument reading is recorded. Signals between the pilot or cameraman and the terrestrial observers must be prearranged. This method is limited to use with low performance aircraft so that satisfactory accuracy may be obtained.

(*c*) *Resection.*

1. Principle. The tracing paper method of resection (par. 246b) can be used to determine the chart locations of plumb points. Instead of being measured with an instrument, the angles are read directly from the oblique photo. Because the front covered by an oblique is limited, care must be exercised in choosing control points.

2. Selection of control points. Three or four control points should be selected; more afford greater accuracy. Their location on the chart must be known or determined. The points should be situated on the photo approximately as shown in figure 83.

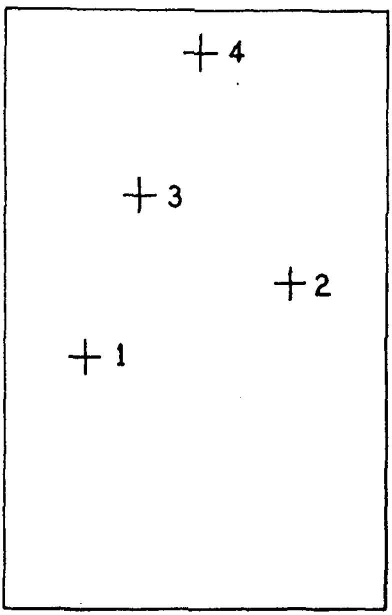


Figure 84. Control points on a chart.

The result of a good selection of control points is shown plotted in figure 84.

If three control points are used, greater accuracy is secured if the center point is at a greater range than the near points. However, care must be taken that the points selected are not on or near the circumference of a circle passing through the plumb point, a condition under which the tracing paper method fails. In open country with numerous landmarks, ideal conditions can readily be obtained. In heavily wooded country or in terrain which has no outstanding landmarks, control points may have to be selected in friendly areas only.

Accuracy of resection will suffer in proportion to the extent of departure from ideal selections.

3. Use of the resector. A resector (substitute for tracing paper) is a thin piece of celluloid, 18 inches square and frosted on one side to permit marking by pencil. It can be used repeatedly. A permanent center line about 15 inches long is scratched on the resector and two tiny pin holes are pricked as shown in figure 85a. A resector is merely a convenience; tracing paper may be used.

In performing a resection for the photograph shown in figure 82, only the coordinates for deflection are needed. With a range-deflection fan, a ray is laid off in pencil, as shown in figure 85b, and labeled Control Point 1. In a similar manner, rays are laid off for control points 2, 3, and 4. The resector should then resemble figure 85c, and should carry a photo identification number or letter. The resector must now be placed over the chart containing control points 1, 2, 3, and 4, and is manipulated until the appropriate rays lie directly over their respective control points (fig. 85d). The chart location of the plumb point is recorded by pricking through the hole of the resector at which the vertex of the fan was placed.

(2) CENTER LINES. Since horizontal angles on the mil-gridded oblique are read from the center line, plotting is facilitated if the same line is drawn on the chart.

When the simultaneous vertical or intersection methods are used to locate the plumb points, the center line may be placed on the chart by using a single control point.

Example: The reading to the control point is L 103. The range-deflection fan, with vertex at the plumb point, is placed on the chart, and an angle of 103 mils is laid off to the right of the control point. The center line is drawn on the chart along the right edge of the fan.

If the resection method of locating the plumb point is used, the center line is recorded on the chart by pricking through while the resector is properly oriented for transferring the plumb point (see (*c*) *3* above).

Each plumb point and center line must be labeled with its photo number or letter designation, and the center lines are marked with identifying arrows, as in fire direction technique.

b. Transposition of points from obliques to chart.

(1) DESIGNATION OF POINT.

(*a*) Oblique coordinates are announced as "Photo 58, L156042." The photo number designates the photo from which the reading was taken. The letter "L" or "R" indicates a reading left or right of the center line. The first three figures represent the horizontal angle from

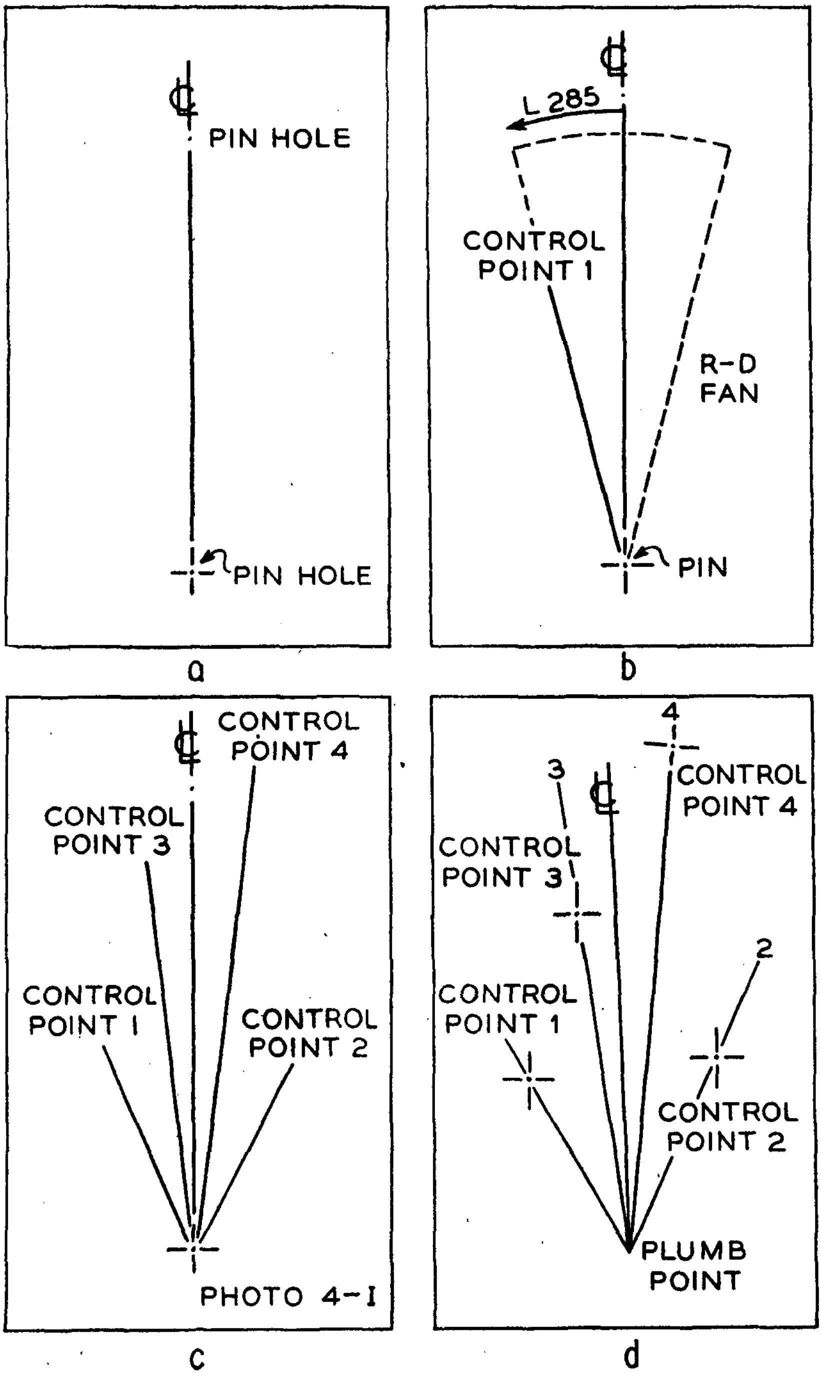


Figure 85. Tracing paper resection to locate plumb points and center lines.

the center line. The last three figures represent the vertical angle from the zero line.

(*b*) There are two ways whereby an observer may designate a point to be plotted.

1. If identification of the point on the photographs is difficult, the observer should, if he has more than one photo, send complete coordinates from at least two.

2. Where the point is easily identified, the observer need only designate the target location on one picture. Fire-direction center will choose one or more additional photos on which the same target is recognized. This latter arrangement is preferable because the observer need concentrate on locating the target on only one photo. Generally, the location will also be more accurate since fire direction personnel may be expected to have a better opportunity to select photographs which will give the best intersection.

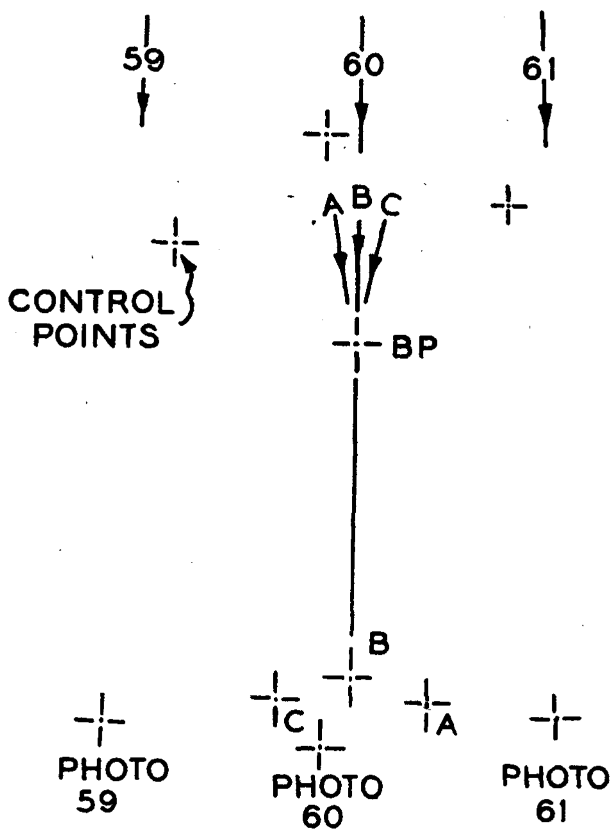


Figure 86. Firing chart showing plumb points and center lines.

The target will often appear on several adjoining photographs. Targets should be indicated from photographs as widely separated as possible.

(2) PLOTTING THE POINT. Figure 86 is an example of a firing chart for oblique photographs. It shows the location of the batteries, plumb points, the center lines, and the control points used in placing center lines for each photo. For convenience, the firing chart for the obliques can be a duplicate of the firing charts used for missions reported by other means or used for planning purposes.

Targets are located from oblique photographs by the plot of the intersection of two or more lines of sight. Example: Using the sample firing chart (fig. 87), assume that an observer sent in the following message, *Photo 59, R210118, infantry platoon with heavy weapons, request battalion, fire for effect.* Fire direction personnel identified the same point on photo 60 as L 60, and on photo 61 as L 305. The target would be plotted as in figure 87.

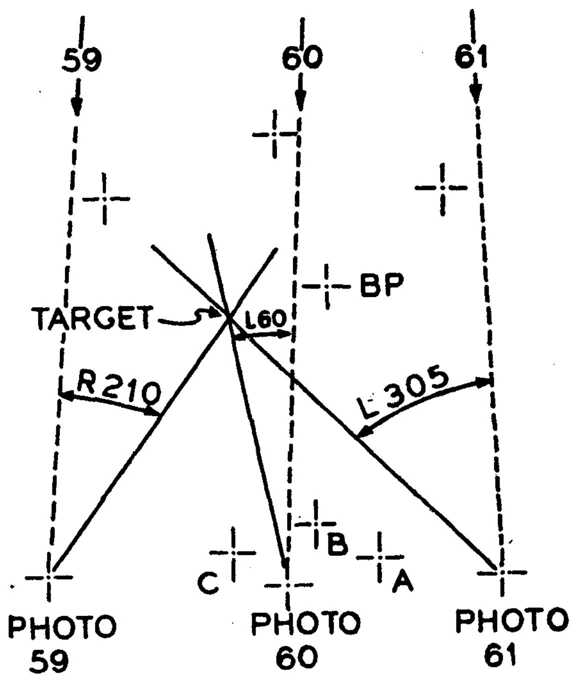


Figure 87. Location of a target on the firing chart.

With a range-deflection fan, a ray is drawn 210 mils right of the center line of photo 59, and another ray is drawn 305 mils left of the center line of photo 61. The intersection of these two rays marks the chart location of the target, which should be checked by plotting a

ray from a third photo (photo 60). The plotting of the location of the target is long base intersection. Any point identifiable on two obliques can be located quickly in a similar fashion.

c. Checks. All work performed in connection with locating points horizontally should be checked to insure accuracy. Any feature appearing on several photographs may be used for checking accuracy. The angular shift to the point on each picture is plotted on the chart. All rays will intersect at a point if the coordinates have been correctly read and if the locations of the plumb points and the directions of the center lines are correct.

An inaccurate orientation or plumb point plot may seem to check perfectly if but one plot of a known point is used in making the check. Therefore, the check should be applied to at least three points. If good intersections are obtained for three features, one in the foreground, one at midrange, and one at extreme range, the resection may be considered correct.

All plumb points and center lines must be checked. If one terrain feature does not appear on all photographs, suitable combinations of photographs must be chosen so as to provide a complete check. A triangle of error which does not exceed 50 yards is allowable.

203. DETERMINATION OF ALTITUDES.

a. Altitude of the camera. When gridded obliques are used in connection with maps having suitable vertical control, map altitudes are generally preferable to those computed by the following method. The altitude of the camera may be determined from the altitude of the terrain appearing in the photograph. Assume that a house, being used for a division artillery control point, appears at a vertical angle of 100 mils in photo 59, and its distance on the firing chart from the plumb point of photo 59 is 3500 yards. Figure 88 shows the relations that exist. From the mil formula, $W = \frac{m}{\!/\!}\;$ — $W = m/_{\!}\!\!$

b. Altitude of the target. The altitude of a target is computed from an oblique photograph after the altitude of the camera has been determined. The difference in altitude between the camera and the target is determined as in figure 88. To establish the altitude of the target, this distance is subtracted from the altitude of the camera. In paragraph 202b (2), an observer sent a message, *Photo 59, R210118', infantry platoon with heavy weapons, request battalion, fire for effect.* The location of the target was plotted, in figure 87 from the deflection

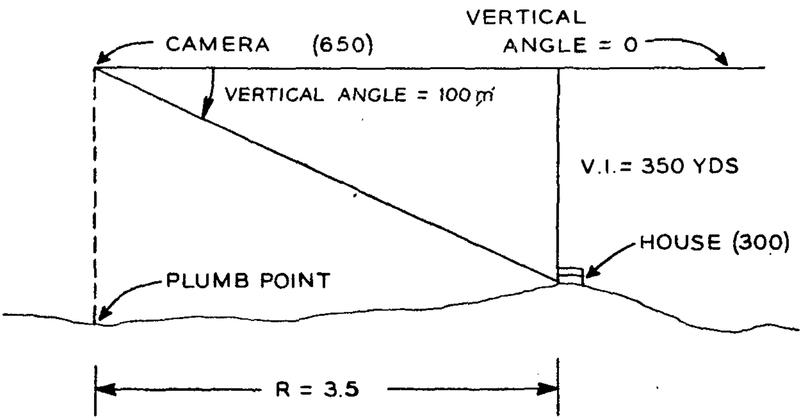


Figure 88. Determination of the altitude of the camera.

coordinate given, and a similar coordinate was obtained from a companion photograph. To illustrate the use of the vertical angle 118, assume the target plotted 3200 yards from the plumb point of photo 59. The vertical interval is 378 yards, and the altitude of the target is 650 − 378 = 272 yards. This system of determining altitudes is predicated on the fact that the horizon line is sufficiently clear to enable the photographer to place the grid properly.

204. OBSERVED FIRE CHART.

a. The use of mil-gridded obliques to supplement an observed fire chart is accurate and may be convenient where survey is slow. The simultaneous vertical can be used expeditiously only when the locating of the plumb point can be included in the position area survey. Locating the plumb point by intersecting the position of the airplane at the instant the picture was taken would be practicable only when a surveyed base had been established.

b. If a simultaneous vertical was taken with the oblique or if the position of the airplane was intersected at the instant the picture was taken, one check point visible on the oblique photograph is selected and registered upon. If the plumb point is to be resected, three or more check points, visible in the oblique photographs, are selected and registered upon. Registrations may be conducted from the air or from observation posts. Site should be stripped from the registrations. The check points are plotted on the observed fire chart from the adjusted data and are then used as control points for orienting the photographs. The control points should be selected as for a surveyed chart (par. 202a (1) (*c*)). Fires will be more accurate inside the pattern of the control points than outside. In the case of targets which when

plotted fall outside the pattern of control points, surveillance of the fires should be provided. This method may be refined, if time and circumstances warrant, by stripping all determinable corrections from the registered data and by using the results in lieu of survey.

205. FIRING WITH ONE OBLIQUE PHOTOGRAPH.

a. If an oblique photograph is taken approximately over the battery position, the oblique photograph grid can be used to measure deflection shifts directly in mils, and to estimate ranges. The height of the camera above the plumb point can be obtained from the altimeter reading in the airplane at the time the photograph was taken (fig. 88). This distance in yards, divided by the vertical angle to the target as measured by the grid, gives an approximate range. The first target taken under fire is used as the base point, and deflection shifts are measured from it on the oblique photograph. The adjusted range is compared with the range computed from the photograph to determine whether the correction is positive or negative.

b. As an example of the use of this method, assume that the first target taken under fire is at (R020191) in the oblique photograph (par. 202b). The actual range fired is 3700, and the photograph was taken at an altitude of 667 yards. The computed range is 667 $\div$ 191 = 3.5 or 3500 yards. The next target is at (L064222). The computed range is 667 $\div$ 222 = 3.0 or 3000 yards, and the deflection shift is left 84 (R 20 to L 64). The basic data to open fire is BDL 84, 3200. The deflection correction and sheaf centering are included in the registration; 200 yards of range are added to correct the range disparity found in registering on the base point. This method is approximate and is suited to country that is flat or rolling, but not to mountainous country; it insures excellent data, but immediate fire for effect is seldom justified.

206. LOCATION OF TARGETS AT NIGHT. By the use of mil-gridded obliques taken simultaneously from surveyed observation posts which form an adequate base for intersection, targets may be located at night. Any camera, the focal length of which is known or can be determined, is suitable. High speed panchromatic film gives best results. Orientation is accomplished by setting up two aiming posts with lights in the field of view of each camera; the surveyed direction to each aiming post from the camera is predetermined. Communication between the observation posts and careful prearrangement are necessary in order that the opening and closing of the camera shutters can be synchronized. The length of exposure depends on the activity in the sector and the assigned mission. Registration of many flashes on

one pair of photographs makes identification of the same target on both obliques difficult. The grid used on the photos is the center section of the plate grid whose construction is described in appendix VI. The grid is oriented to the photograph when the horizontal and vertical axes of the grid are placed over the horizontal and vertical axes of the photo. Targets are plotted on the firing chart as described in paragraph 202b (2); the aiming post lights are used as control points.

CHAPTER 4
SURVEY EQUIPMENT AND ITS USE

Section I. PRINCIPAL INSTRUMENTS

207. PRINCIPAL INSTRUMENTS. The principal instruments used for survey operations are the tape, the aiming circle, the battery commander's telescope, the transit, the altimeter, and the military slide rule. Detailed description of the aiming circle is given in TM 6–220. Detailed descriptions of the tape and the transit are given in TM 5–235

Section II. THE TAPE AND TAPING

208. THE TAPE AND ACCESSORIES.

a. Tape. Field artillery survey sections are equipped with 300-foot tapes and 100-foot tapes. Both types of tapes may be graduated throughout their length into feet and tenths, or only the foot marks may be shown, and one foot on both or on one end of the tape divided into tenths. The graduated foot or feet may be included within the 100 or 300 feet, or they may be outside the 100 or 300 feet.

b. Accessories. Each tapeman should be equipped with a plumb bob and cord and a notebook. The head tapeman should have a set of 11 pins.

209. PERSONNEL. Two individuals, called head and rear tapemen, are required to determine distances by taping.

210. TAPING ON LEVEL GROUND. The head tapeman with the 300- or 100-foot end of the tape in his hand, after setting one pin at the starting point and checking to see that the remaining 10 pins are on his ring, starts along the course to be taped. The tape is allowed to drag on the ground, the rear tapeman watching it only to prevent its snagging. Just before the whole length of the tape is drawn out, the rear tapeman calls, "Halt," at which the head tapeman turns and straightens the tape on the true line (par. 212). When the tape is on the true line, the rear tapeman calls, "Pull," and the head tapeman

pulls on the tape until it is properly taut (par. 212). The rear tapeman guides the zero exactly over the starting point and calls, "Stick." At this instant, the head tapeman sets his pin to correspond with the 300- or 100-foot mark of the tape and responds, "Stuck." When both tapemen have checked for accuracy, the rear tapeman pulls his pin. Both now proceed, the rear tapeman giving the preliminary "Halt" signal as his end of the tape approaches the pin just set by the head tapeman. The tape is lined up and stretched, the front pin is set, and the rear pin pulled on signal, as described for the first tape length. This process is repeated until the head tapeman has set his last pin, at which time he calls, "Tally." The rear tapeman goes ahead, counting his pins as he goes, and, if there are 10, transfers them to the head tapeman who also counts them and replaces them on his ring. This exchange is known as a tally and means that 10 tape lengths have been measured from the starting point or from the last tally. Both tapemen record each tally in their notebooks. A similar check of pins may be made at any time by remembering that the sum, omitting the one in the ground, should be 10. Frequent checks detect the loss of a pin and the consequent loss of a tape length. The rear tapeman does not give his pins to the head tapeman on a mere check of pins. When the end of the course is reached, if the last measurement is not an even tape length, the head tapeman continues past the station until the usual signal of "Halt." He then returns to the station. The manner of determining the last measurement, if it is not an even tape length, will depend upon the type of tape being used:

a. If the tape is graduated in tenths of a foot through its entire length, the rear tapeman holds zero over the pin and the head tapeman reads the feet and fraction direct.

b. If only the first foot, that is from zero to 1, is graduated in tenths of a foot, the rear tapeman holds the 1-foot mark of the tape opposite his pin, and then slacks off sufficiently to allow the head tapeman to bring a whole foot mark into coincidence with the front pin. Then the head tapeman reads the whole number of feet and the rear tapeman reads the fraction. The fraction read is subtracted from the whole number of feet to determine the last measurement.

c. If an additional foot, that is, a foot beyond the zero, is graduated in tenths of a foot, the rear tapeman holds the zero about even with the pin. The head tapeman then pulls the tape until an even foot is opposite his pin and reads the feet. The rear tapeman reads the tenths of a foot and the fraction is added.

When the last measurement has been made, the rear tapeman goes forward, counts his pins, and gives them to the head tapeman. The length of the course is the sum of the whole tape lengths plus the

length of the last measurement. Both tapemen compute and enter the length of the course in their notebooks. Only the results of their computations are checked one against the other.

211. TAPING ON SLOPING GROUND.

a. General. In measuring on a slope there are two ways of getting horizontal distance: to measure along the slope and to correct this measurement by calculation, known as slope taping; or to hold the tape horizontal and to determine the horizontal distance directly, known as breaking tape. The methods of marking points and recording distances in taping on slopes is identical with taping on level ground.

b. Slope taping. In this method, the tape lies on the ground and the slope distance is measured. The angle of slope is measured with an instrument. The taped distance multiplied by the cosine of the angle of slope is equal to the horizontal distance. TM 5–236 provides tables which reduce the amount of computations. This method is suitable only for gradual and evenly sloping terrain.

c. Breaking tape. In this method, the head tapeman goes forward the entire length of the tape, dropping the tape approximately on line. He then comes back toward the rear tapeman until he reaches a point at which a fractional part of the tape when held level is not above shoulder height. The fractional part should be a multiple of 10 feet. On steep slopes, the taping must be done in short sections. In measuring downhill, the head tapeman sets a pin at the point on the ground beneath the plumb bob. He keeps his finger at the fractional reading on the tape until the rear tapeman comes up. In measuring uphill, the process is reversed, the rear tapeman holding his point on the tape over the point on the ground by means of the plumb bob, while the head tapeman sets his pin. In both cases, every time the rear tapeman takes over a point from the head tapeman, the rear tapeman gives the head tapeman a pin to replace the one in the ground which represents only a fractional part of the tape length. This exchange continues until a full tape length has been measured, at which time the rear tapeman retains the pin.

212. ALINEMENT, TENSION, AND SAG.

a. Alinement. Alinement of the tape during the measuring is performed by the tapemen without help from the instrument man. If the next station has been selected, it is marked by the rodman; the rear tapeman lines the head tapeman in by eye. When the course to the next station is selected before the station is established, the direction of the course should be toward some unmistakable object. The rear tapeman then lines the head tapeman in on the selected course. Dur-

ing the crossing of low ground, it may be necessary for the head tapeman to line himself in with the rear tapeman and the last station. Lining tapeman in with an instrument is an unnecessary refinement.

b. Tension and sag. With the tape resting on the ground, a pull of approximately 20 pounds must be exerted. When the tape is suspended in the air for plumbing, the tension should be increased to counteract the sag; an unsupported length of about 100 feet requires a pull of about 25 pounds. Unsupported lengths greater than 100 feet introduce errors in measurements and should not be used.

213. TRAINING TAPEMEN.

a. General. Tapemen should be carefully trained. Prescribed methods should be rigidly enforced. Tapemen must exercise constant vigilance to avoid errors and blunders. The most common blunders are: misreading the tape; failing to record a complete tape length; failing to consider errors in the length of the tape caused by repairs of the tape.

b. Don'ts for tapemen.

(1) Don't jerk the tape.

(2) Don't pull the tape when it is kinked.

(3) Don't let vehicles run over the tape.

(4) Don't bend the tape sharply around corners.

(5) Don't split hairs in lining in.

(6) Don't allow the chaining pin to be disturbed.

(7) Don't pull the pin until you are sure that it will not be needed again.

(8) Don't break tape oftener than necessary. Each break slows up the work and introduces another chance for error.

(9) Don't fail to wipe the tape clean and dry before putting it away.

(10) Don't forget that methodical procedure is speedy and prevents errors.

Section III. THE AIMING CIRCLE AND BATTERY COMMANDER'S TELESCOPE

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214. THE AIMING CIRCLE. In survey, the aiming circle is used to measure horizontal angles, to measure limited vertical angles, and to measure azimuths by magnetic needle.

215. BATTERY COMMANDER'S TELESCOPE. The battery commander's telescope is designed primarily for observing artillery fire. However, since means are provided for the measurement of both horizontal and vertical angles to the nearest mil, it may be used in lieu of

a transit or aiming circle for survey work, as the methods of employment are similar. This instrument can be used to good advantage in survey work, particularly on a target area base because its greater optical power will aid in the location of targets.

a. It is not comparable to the transit in accuracy but it does have some definite advantages over an aiming circle. They are:

(1) Ability to measure vertical angles of 300 mils above or below the horizontal plane.

(2) Greater optical power and wider field of vision.

(3) Four different filters to aid in observation under various climatic conditions.

(4) Usefulness in fox holes, trenches, etc. (only the lens shows above ground).

b. Its disadvantages are:

(1) It is heavier than the aiming circle and therefore more difficult to move rapidly.

(2) It has a relatively high silhouette (unless dug in).

216. MEASURING HORIZONTAL ANGLES. To obtain accurate measurements of horizontal angles, the spherical bubble must be centered and the following precautions taken:

a. When a setting is made, the last movement of the vertical hair should always be in the same direction, usually clockwise. If the object is overrun, the hair is moved well back of the object and moved up to it again. This procedure eliminates the effect of lost motion. As a check after a measurement is made, the hair is brought back to the origin. If the index varies materially from the proper reading, the measurement is thrown out. Angles should be read twice to prevent gross errors of 10 or 100 mils. Reading an angle more than once is known as making a multiple reading.

b. The size of the possible error is reduced if the instrument is read to the tenth of a mil, by interpolation between the mil graduations on the micrometer scale.

c. The most accurate horizontal reading is obtained by repeating the measurement three times cumulatively, and taking the average. For example: the angle between two points, A and B, is to be measured cumulatively three times. With the scale set at zero, the line of sighting of the instrument is directed at A with the lower motion. The angle to B is then measured with the upper motion (assume a reading of 205.2 mils). The instrument is again directed at A with the lower motion, without changing the reading, and the angle to B measured again (assume a reading of 411 mils). The angle is measured a third

time in the same manner (assume a reading of 615.9 mils). This value, 615.9 mils, is divided by the number of readings to give 615.9/3 or 205.3 mils.

217. ACCURACY. In one reading of an angle with an average aiming circle, or battery commander's telescope, carefully operated as described above, an error as large as 1 mil will not be unusual. This instrument error is unpredictable. However, ordinarily it will be reduced by cumulative readings. The cumulative readings should be limited to three. Readings in excess of three do not increase accuracy because operator errors become excessive.

218. MEASURING VERTICAL ANGLES. For reliable work in measuring vertical angles, the aiming circle or battery commander's telescope must be accurately tested and its correction constant determined.

219. CHECKING THE LEVEL LINE OF THE AIMING CIRCLE OR BATTERY COMMANDER'S TELESCOPE. The level line of the instrument may be determined by either of the following methods:

a. If the altitudes of two points and the distance between the points can be determined, the true vertical angle may be computed. The instrument is set up at one of the points and the vertical angle to the other point is measured. To determine the correction constant, subtract the measured angle from the computed angle. The correction constant is applied algebraically to all measured vertical angles. The accuracy of the correction can be increased by using the mean of corrections obtained on a number of points.

Example: The computed vertical angle from A, where the instrument is set up, to B is +15 mils. The vertical angle from A to B as measured with the instrument is +12 mils. The correction constant of the instrument is +3 mils which will be added to all vertical angles measured with this instrument.

b. The alternate method which requires no known altitudes is as follows: two stations are established on the ground 75 to 100 yards apart. At each station a stake with a flat smooth top surface is driven or a stone with a flat top surface is seated firmly in the ground. The instrument to be calibrated is set up over station 1 and leveled with the objective lens slightly in rear of a pole held in a vertical position resting on the stake or stone. The height of instrument is then marked on the pole at the same height as the center of the objective lens, by determining the radius of the objective lens and applying it in the proper direction to the height determined for the top or bottom of the objective lens. The pole is then taken to station 2 and held vertically on the stone or stake there. The angle of site to the height of

instrument mark is then measured with the instrument and noted. Clarity of sighting is improved if the edge of a card or other well defined straight edge is held horizontally in contact with and just below the pencil mark on the pole. The instrument is set up over station 2 and the entire precedure is repeated, step for step. (CAUTION: The height of instrument as set up at station 2 must be marked on the pole and used as the sighting point when the pole is set up at station 1.) If the algebraic sum of the two angles of site measured equals 0, the instrument is in adjustment and no correction need be applied to readings taken with it; for example:

Site measured at station 1	=	+5 ₥
Site measured at station 2	=	−5 ₥
Algebraic sum	=	0

If the algebraic sum of the two angles of site is other than 0, the instrument is in error by one half of this amount. The sign of the error is the same as the sign of the algebraic sum of the two angles of site. The correction is applied in the opposite direction; for example:

Site measured at station 1	=	+5 ₥
Site measured at station 2	=	−8 ₥
Algebraic sum	=	−3 ₥
Error (−3/2)	=	−1.5 ₥
Correction	=	+1.5 ₥

The correction is applied to each angle of site read thereafter, unless the instrument contains an angle of site micrometer which can be adjusted to the true setting.

220. CENTERING THE NEEDLE. For precise work, the average of several trials is taken as follows:

a. Set the scales at zero and center the needle with the lower motion.

b. Using the upper motion, bring the line of sighting to some well defined object and note the scale reading.

c. Repeat the operations three to six times and take the average of the readings.

d. Set this average on the scales and lay on the object. The 0-3200 line of the instrument will be on compass north.

221. DECLINATION.

a. A declination constant is the clockwise angle between *Y*-north and compass north; in other words, the *Y*-azimuth of compass north. This constant is recorded for any instrument equipped with a magnetic needle; the constant for any one instrument may vary in different localities; in any one locality the constant will vary slightly for different instruments.

b. When practical, a declination station is established for determining the declination of instruments. The point chosen for the station should afford a view of at least one distant, well defined point with a direction of known *Y*-azimuth; additional points are desirable as a check. The *Y*-azimuths may be determined by the application of the known grid declination for the area to the true azimuths determined by astronomic methods, by computing the azimuth of the distant point, or by measuring the *Y*-azimuths on a battle map. If the grid declination is unknown, all instruments should be declinated to true north or if true north cannot be determined, all instruments may be declinated to a magnetic azimuth determined by measurement with one aiming circle. In the absence of an established declinating station, an instrument may be declinated for a particular locality on any line of known azimuth.

c. Set up the aiming circle over the declinating station and level the instrument carefully. Set the scales at zero and center the needle. With the upper motion, turn to the point of known azimuth and record the reading. Repeat this process three times and subtract the mean of these readings from the known *Y*-azimuth (adding 6400 mils to the *Y*-azimuth if necessary). The result is the declination constant of the instrument. If more than one point of known *Y*-azimuth can be seen, readings are made for each point, the computation repeated for each, and the mean of the differences taken as the declination constant.

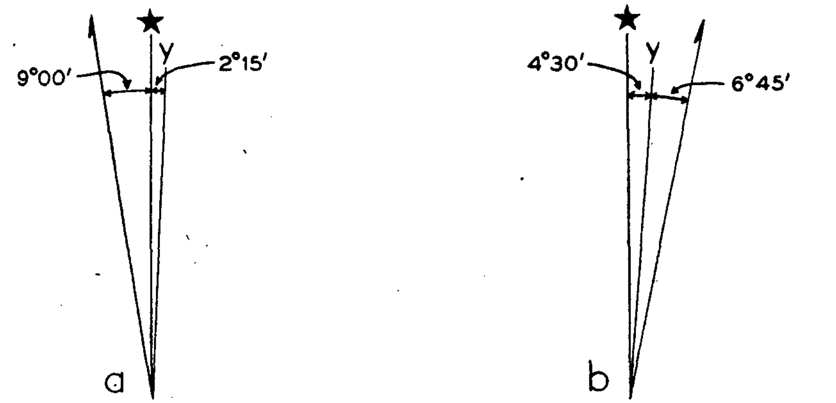
d. If an aiming circle is to be declinated in one locality for use in another locality, follow the procedure shown below.

(1) On the map of the area where the instrument is to be declinated is found the information shown in figure 89a. From this the following is determined:

The *Y*-azimuth of magnetic north is 348° 45′, or	6200 mils
This would be the declination constant of an instrument having no error.	
Declination constant of aiming circle determined as above	6184 mils
Instrument correction of aiming circle	−16 mils

(2) On the map of the area where the instrument is to be used is found the information in figure 89b. From this is determined the *Y*-azimuth of magnetic north which would be 6° 45′ or 120 mils, which would be the declination constant of an instrument having no instrument error.

(3) The declination constant of the instrument for the new locality would be 120 mils minus 16 mils or 104 mils.



DECLINATION INDICATOR FOR LOCALITY WHERE INSTRUMENT IS TO BE DECLINATED

DECLINATION INDICATOR FOR LOCALITY WHERE INSTRUMENT IS TO BE USED

Figure 89. Marginal information taken from map, to be used in the declination of an instrument.

222. LAYING ON A GIVEN *Y*-AZIMUTH. To place the 0-3200 line of the aiming circle on *Y*-north, set the declination constant on the scales and, using the lower motion, center the needle. To place the 0-3200 line of the instrument on a line of designated *Y*-azimuth, subtract this azimuth from the declination constant (with 6400 added when necessary), set the remainder on the scales, and, using the lower motion, center the needle.

223. MEASURING *Y*-AZIMUTH. To measure the *Y*-azimuth to a point, set the declination constant on the scales and, with the lower motion, center the needle. With the upper motion, bring the vertical hair to the point, and the reading on the scales is the *Y*-azimuth.

Section IV. THE TRANSIT AND ACCESSORIES

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224. USE OF THE TRANSIT. The transit is used in field artillery survey for measuring horizontal and vertical angles and for measuring distances by stadia. In battalions having only one transit, the transit normally is used for position area or connection survey. In heavy artillery survey, practically all angles are measured with the transit.

225. TRANSIT SCALES.

a. General. The transit has two scales which are used in conjunction to determine angular measurements. These scales are the main scale and the vernier.

b. Horizontal scales. The main scale is a complete circle graduated primarily from 0 to 360 degrees. There are two sets of numbers on the main scale. *The numbers of the inner set increase from 0 to 360 in a* clockwise direction. The numbers of the outer set increase from 0 to 360 in a counterclockwise direction. The main scale turns only with the lower motion of the transit. The vernier is an arc rotating edge to edge with, and inside of, the main scale. It is an auxiliary scale used for reading fractions of the smallest division of the main scale, and its graduation is dependent upon the graduation of the main scale. The vernier rotates with the telescope.

c. Vertical scales. The vertical scale differs from the horizontal scale in the following respects: the main scale is inside of the vernier; the main scale rotates with the telescope while the vernier is fixed; the largest numeral on the main scale is 90 degrees. Vertical scales are graduated to read to 1 minute. They are read in exactly the same manner as are the horizontal scales of the 1-minute transit (par. 226).

d. Types. The two transits commonly used in field artillery survey are the 1-minute transit, which can be read to 1 minute, and the 20-second transit, which can be read to 20 seconds.

226. READING HORIZONTAL ANGLES ON THE 1-MINUTE TRANSIT

(fig. 90). The main scale of the 1-minute transit is graduated to 30 minutes, and the vernier to 1 minute. To read the angle when the measurement is complete, read the main scale opposite the center of the vernier. If the center of the vernier falls between two main scale graduations, the graduation giving the smaller angle is read. In figure

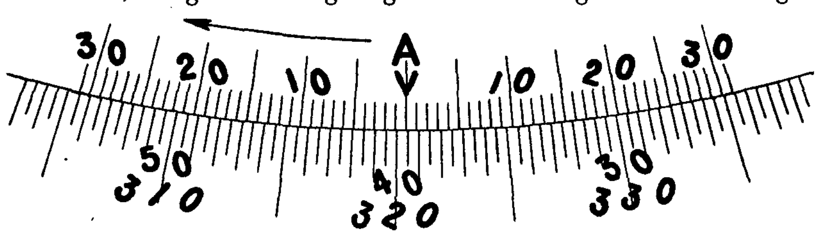

Figure 90. Scales of the 1-minute transit.

90 the main scale reading (clockwise angle) is 39° 30′. The vernier is read by continuing in the same direction as the main scale reading (as indicated by the arrow in figure 90). A further aid in determining which side of the vernier to read is furnished by the numerals on the

scales. The side of the vernier on which the numerals slant the same way as those read on the main scale is the correct side. To read the vernier, follow along the scales until a graduation on the vernier is found that coincides with a graduation on the main scale. Read the value of this graduation on the vernier (in figure 90 it is 4′), and add it to the main scale reading. The complete reading in figure 90 is 39° 30′ + 4′ = 39° 34′. To read the counterclockwise angle, the same procedure is followed. The counterclockwise reading in figure 90 is 320° + 26′ = 320° 26′.

227. READING HORIZONTAL ANGLES ON THE 20-SECOND TRANSIT (fig. 91). The main scale of the 20-second transit is graduated to 15 minutes. The vernier is graduated in minutes and each minute is graduated to 20 seconds. The procedure in reading the 20-second transit is the same as in reading the 1-minute transit. The main scale is read opposite the center of the vernier. In figure 91 the clockwise main scale reading is 90° 15′. The correct side of the vernier is selected as for the 1-minute transit, the coinciding graduations found, and the value read from the vernier. In figure 91 the vernier reading, clockwise, is 11′ 40″. The complete clockwise reading for figure 91 is 90° 15′ + 11′ 40″ = 90° 26′ 40″. The counterclockwise reading in figure 91 is 269° 30′ + 3′ 20″ = 269° 33′ 20″.

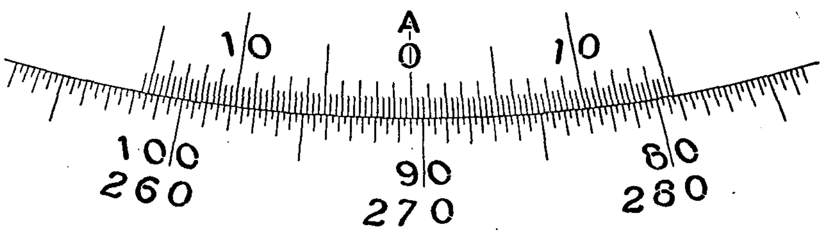

Figure 91. Scales of the 20-second transit.

228. SETTING UP THE TRANSIT.

a. When setting up the transit, place one of the tripod legs in approximately the correct position with reference to the station mark; then manipulate the other two legs so that the plumb bob is brought approximately over the mark, and, at the same time keep the leveling head approximately level. On hillsides, one tripod leg should be uphill, the other two downhill. Keep the tripod bolt nuts sufficiently tight so that they will just sustain the weight of the legs when the instrument is lifted. Press the tripod shoes firmly into the ground to insure rigidity. If the plumb bob is nearly over the mark, final centering may be accomplished by moving the shifting plate after loosening the leveling screws.

b. When leveling the instrument, turn the plates so that each level of the plate is parallel to a pair of diagonally opposite leveling screws. Great care should be exercised when leveling. Initially, all screws should have contact with the plate; one or more loose screws will cause the plate to tip. The screws must not be so tight as to injure the instrument and strain the metal. To level, grasp one pair of opposite screws between the thumbs and forefingers and turn so that the thumbs move toward each other or away from each other, thus tightening one screw and loosening the other. The motion of the two screws should be uniform to prevent binding; one screw descends as fast as the other ascends. After one bubble has been brought nearly to the center of its tube, the other bubble is centered in a similar manner. Instead of getting one bubble centered exactly, it is better to get both bubbles approximately centered, after which one bubble and then the other may be exactly centered. When both bubbles are exactly centered, turn the plate through 180 degrees. Any error in the plate levels will then be evident. To correct the error, move the bubbles toward the center one half of the deviation. After the instrument is leveled, check the plumb bob to see that it has not been moved from the mark during the leveling process.

229. TO MEASURE A HORIZONTAL ANGLE.

a. With the instrument set up over the station at which the angle is to be read, set the zero of the vernier opposite the zero of the horizontal circle, using the upper clamp and tangent screw to bring them to coincidence. Using the lower motion, point approximately at the first object by looking over the top of the telescope. Move the telescope until the vertical cross hair is very nearly on the point, clamp the lower plate by means of the lower clamp thumb screw, and set exactly on the point by using the lower clamp tangent screw. The line of sight is now on the first object. To measure the angle, loosen the upper clamp, turn the telescope to the second point, set approximately on the point, clamp the upper plate, and set the vertical cross hair exactly on the point by means of the upper tangent screw. The angle is then read by means of the vernier, which was set at zero. Never overrun the point in bringing the vertical cross hair upon it. Bring the cross hair to the point in such a manner that the tangent screw compresses the spring against which it works. This procedure eliminates lost motion in the plates.

b. A complete measurement of any angle should consist of the mean of two readings, one with the telescope direct and one reversed. The angle is first measured as described in subparagraph a above; the telescope is plunged (rotated 180 degrees in a vertical plane) and, using

the lower motion only, the first object is sighted upon; using the upper motion, the telescope is set exactly on the second object; the reading on the vernier which was originally set at zero now gives twice the value of the angle desired. This method removes most of the errors of instrument adjustment.

230. TO MEASURE A VERTICAL ANGLE. Vertical angles are measured with the transit as follows: Level the horizontal plate accurately. Sight on the distant point with the telescope direct, and read the vertical angle. Plunge the telescope, rotate the instrument in azimuth 180 degrees, sight on the point, and read the vertical angle again. The mean of the two readings is taken.

231. RANGE POLES. Range poles are usually 8 or 10 feet long, round or hexagonal, and about 1 inch in diameter. They are made of wood shod with iron point, or of steel rod or tubing; they are graduated in feet, the graduations being painted alternately red and white. The range pole is used to mark a point on the ground so as to make it visible from a distance. The rod is plumbed by balancing it between the finger tips of both hands, the rodman standing squarely behind it, facing the instrument. The rod also may be used to mark points along a line of sighting. In this case, to locate the point, the rodman carries the pole vertically, moving right, left, backward, or forward, as directed by a signal from the instrument man.

232. STADIA.

a. The stadia is a device for measuring distances which are read on an intercept on a graduated rod; it is used when great precision is not required. For this purpose, there are two additional horizontal hairs, called stadia hairs, in the transit telescope on the same reticle as the cross hairs.

b. Stadia rods (fig. 92). Stadia rods are 12 feet long, graduated to 0.05 feet, and self reading.

c. Use of the stadia. The transit is constructed with its lower and upper stadia hairs so placed that the intercepted part of a rod, held perpendicular to the line of sight, multiplied by 100, is equal to the distance between the instrument and the point on which the stadia rod is read. Since usually it is not practical to hold

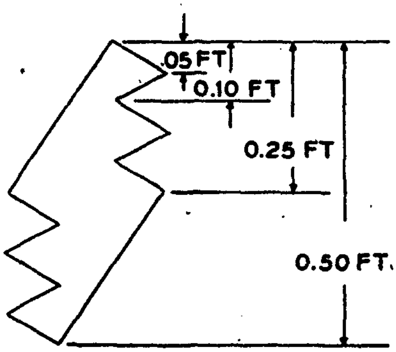

Figure 92. Fractional foot graduations on stadia rod.

the stadia rod perpendicular to the line of sighting, the rod is always held plumb, and the resulting intercept is adjusted. This adjustment is based on the vertical angle from the transit to the rod and is made by use of a stadia computer (TM 5–235), or by use of stadia reduction tables (TM 5–236). The distance obtained by this adjustment, using either the tables or the computer, will be the true horizontal distance from the transit to the stadia rod.

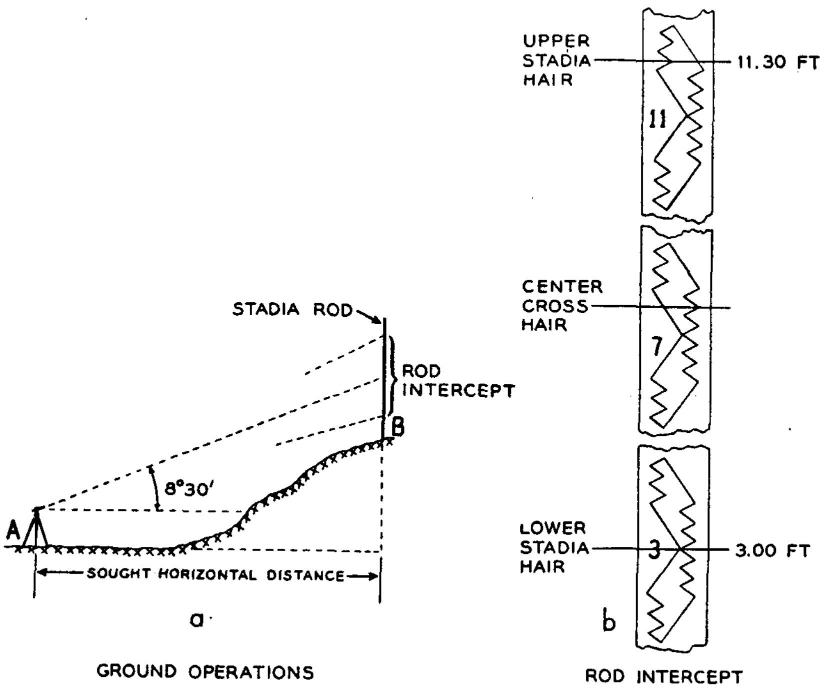

Figure 93. Determining horizontal distance with the transit and stadia.

d. Example (fig. 93). The true horizontal distance from A to B is determined as follows:

Reading at upper stadia hair	11.30 feet
Reading at lower stadia hair	3.00 feet
Rod intercept	8.30 feet
Horizontal distance for rod intercept of 1 foot at vertical angle of 8° 30′ as taken from stadia reduction tables	97.82 feet
Rod intercept	× 8.30 feet
Horizontal distance from A to B	811.9 feet

233. STADIA CONSTANTS.

a. With some transits, a correction $(c + f)$ must be added to the distance determined by stadia. The $(c + f)$ is recorded in the transit case by the manufacturer. An explanation of its derivation is given in TM 5–235.

b. With some transits the rod intercept is multiplied by a number other than 100 to determine the distance. This number is called the *K*. Transits when delivered by the manufacturer have no *K*. If the stadia wires are replaced in the field, the *K* can be determined as prescribed in TM 5–235.

Section V. THE ALTIMETER

234. DESCRIPTION AND USE.

a. (For detailed information see TM 5–9420.) The surveying altimeter is an aneroid barometer graduated to read altitude in feet. It is mounted in a wooden case about 6 inches square and 4 inches deep. The mechanism is rigidly attached to a top plate on the front of which the dial is inscribed. The case proper is covered with a plastic window. In the plastic window is a plastic plug which may be unscrewed to give access to a screw in the face of the dial. The indicator hand may be set to agree with another altimeter by slowly turning the screw in the face of the dial. This adjustment is confined to 100 or 200 feet, and care should be taken not to force the adjusting screw beyond its limit. The scale on the dial of the altimeter extends from 0 to 7000 feet and is graduated in 10-foot intervals. In order to avoid negative readings in absolute altitude, the scale is so graduated that the 1000-foot mark on the dial corresponds to 0 altitude under normal atmospheric conditions. When the altimeter is read, parallax is eliminated if the eye is placed so that the point of the indicator hand appears exactly superimposed on the reflected image of the hand in the mirror around the outer edge of the dial.

Generally, the error in altitudes obtained by altimeter readings does not average over 4 or 5 feet, and the maximum error seldom exceeds 8 feet, if certain precautions are observed. In order to secure such accuracy, corrections must be made for the variations in barometric pressures which occur during the series of observations. For that reason, one instrument, known as the station altimeter, is read at a point of known (or assumed) altitude every 5 minutes during the entire work period. Starting with an observation at the station alti-

meter, the second altimeter, called the field altimeter, is observed at points whose altitudes are desired, and then a final reading is made at the station altimeter. Each reading of the field altimeter is made simultaneously with a reading of the station altimeter. For best results, the field altimeter should remain within a radius of 6 or 8 miles of the station altimeter, and not more than 4 hours should elapse from the time of the initial reading to the time of the final reading of the field altimeter at the base station altimeter. Simultaneously with each reading of the station or field altimeter, temperature at the instrument is recorded so that the indicated differences of altitude may be corrected in accordance with the mean of the temperatures at the two instruments.

A thermometer, graduated from —60° to +160° Fahrenheit, is issued with each altimeter. A temperature correction nomograph is found inside the cover of each altimeter. On the right is a scale of observed difference of altitude, on the left is a scale of mean temperature of the two observations, and in the center a temperature correction scale. By setting the sliding index at the apparent altitude difference on the right and the mean temperature of the two stations on the left, the temperature correction will be found intersected on the center scale by the index. The mean temperature scale indicates whether the correction is plus or minus, and whether it is applied as read, or whether only one tenth of the read value is applied. Between the three scales described above is a foot-millibar scale. These scales are for use in taking meteorological readings and are not used in field artillery survey.

b. A centrally located base station of known or assumed altitude is selected. The station altimeter and the field altimeter are allowed to stand for about 10 minutes at the base station in order that both may become fully adjusted to pressure and temperature. They are then set in agreement (a above), or the difference, called index difference, is read and noted for future use as a correction to all readings of the field altimeter. Watches must be synchronized. After the initial reading has been made and the time and temperature noted, the field altimeter is transported to points the altitudes of which are desired. At each field station, the altimeter is placed in position, and an interval of 5 to 10 minutes is allowed to elapse before readings are taken, to permit the instrument to stabilize. Observations of indicated altitude, time, and temperature are then made and recorded. After observations have been made at all desired points, the field altimeter is returned to the base station and a final observation is made of altitude, time, and temperature. While the field altimeter is carried to the points the altitudes of which are desired, the station altimeter remains at

the base station and the altitude is observed every 5 minutes along with the temperature and the time. If, at the final observation, the altitude readings of the two altimeters do not agree after the index difference has been applied, the difference is divided by the number of minutes elapsed since the initial observation. This procedure will give an adjustment factor, which, when multiplied by the elapsed minutes from the time of the initial observation to the time of the observation at any station, will result in the correction to be applied to the altitude of that station.

c. The use of the altimeter is illustrated by the following example:

(1) Observations have been made as follows:

Initial observations at base station.

	TIME	ALTIMETER READING	TEMPERATURE
Station altimeter	0835	872	34°
Field altimeter	0835	792	34°

Index correction
(difference) = (872 − 792) = +80

Subsequent observations.

STATION ALTIMETER

TIME	ALTIMETER READING	TEMPERATURE
****	***	***
0950	885	36°
0955	887	36°
****	***	***

FIELD ALTIMETER

STATION	TIME	ALTIMETER READING	TEMPERATURE
Btry A	0950	985	32°

Final observations at base station.

	TIME	ALTIMETER READING	TEMPERATURE
Station altimeter	1015	869	32°
Field altimeter	1015	784	32°

(2) Difference in altitude between base station and Battery A has been determined as follows:

Observed altitude at Btry A at 0950	985
Index correction	+80
	1065

Corrected altitude at Btry A at 0950	1065
Observed altitude at base station at 0950	−885
Apparent altitude difference	+180
Temperature correction from nomograph corresponding to altitude difference of +180 feet and mean temperature of $\left(\dfrac{36° + 32°}{2}\right) = 34°$	−6
Corrected altitude difference	+174
Closure adjustment:	
Error of closure = 869 − (784 + 80) = −5 feet	
Elapsed time from initial to final observation = 100 minutes (*i.e.,* 1015 − 0835)	
Adjustment factor = +5/100 (sign opposite to that of error)	
Elapsed time from initial observation to Battery A observation = 75 minutes (*i.e.,* 0950 − 0835)	
Adjustment (75 × 5/100)	+4
Adjusted altitude difference	+178

d. Hints for use of altimeters:

(1) Protect from sun and strong wind.

(2) Altimeters must be in horizontal position when observed.

(3) Do not lay altimeter on the ground to make observation.

(4) Avoid shocks and jars. *Tapping* the instrument prior to observation is unnecessary and may be harmful. Keep instrument away from field pieces which are firing.

(5) Best results may be obtained from 2 to 4 hours after sunrise or before sunset. Avoid midday observations.

(6) Avoid observations during thunderstorms, whirlwind, or squall conditions.

Section VI. THE MILITARY SLIDE RULE

235. USE. The military slide rule can be read with an accuracy of 1 in 500, and is therefore suitable for all computations where that accuracy need not be exceeded.

CHAPTER 5

BASIC SURVEY OPERATIONS AND METHODS

Section I. GENERAL

236. BASIC OPERATIONS. The basic operations used to obtain necessary ground data are the measurement of angles and distances. These operations are performed as prescribed in chapter 4, PART FOUR. The ground data, when obtained, are converted to chart data by plotting or computing, or by a combination of the two.

237. METHODS. The two basic ground operations, measuring angles and measuring distances, are combined into methods for determining distances, methods for locating points, and methods for determining and transmitting direction.

Section II. DETERMINATION OF DISTANCES

238. METHODS. The tape and the transit with stadia provide two methods of determining distances (chapter 4, PART FOUR). Additional methods are short base intersection, right angle base, and aiming circle stadia. Determination of distance by the latter three methods is dependent on the solution of triangles.

239. SOLUTION OF THE RIGHT TRIANGLE (fig. 94).

a. For computing the sides and angles of a right triangle, the following formulas are used:

(1) $A + B + C = 3200$ mils (or 180°)

(2) $\text{Sin } A = \dfrac{a}{c} = \dfrac{\text{opposite}}{\text{hypotenuse}}$

(3) $\text{Cos } A = \dfrac{b}{c} = \dfrac{\text{adjacent}}{\text{hypotenuse}}$

(4) $\text{Tan } A = \dfrac{a}{b} = \dfrac{\text{opposite}}{\text{adjacent}}$

(5) $\text{Cot } A = \dfrac{b}{a} = \dfrac{\text{adjacent}}{\text{opposite}}$

(6) $a^2 + b^2 = c^2$

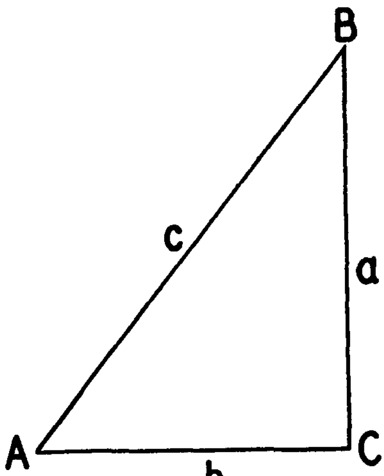

Figure 94. The right triangle.

b. In addition to their use in determining distances, the formulas listed above are used extensively for the computation of coordinates from azimuth and distance (par. 265) and for the computation of azimuth and distance from coordinates (pars. 263 and 264).

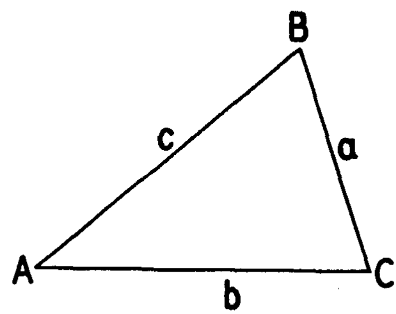

Figure 95. The oblique triangle.

240. SOLUTION OF THE OBLIQUE TRIANGLE (fig. 95). For computing the sides and angles of an oblique triangle, the following formulas are used:

a. $A + B + C = 3200$ mils (or 180°)

b. $$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

c. Other formulas of occasional value in field artillery survey are given in TM 5–235.

241. SHORT BASE INTERSECTION.

a. Application. When the angle of intersection of the rays from the ends of a base to a desired point is less than 500 mils, short base methods *must* be used. If the angle of intersection exceeds 500 mils, these methods may be used.

b. Solution of a triangle to determine distance (fig. 96). It is desired to determine the distance from A to C. The base AB has been established and its length determined, and the angles at A and B have been measured. The distance AC is computed as follows:

$$\begin{aligned}\text{Angle } C &= 3200 \text{ ₥} - (A + B)\\ &= 3200 \text{ ₥} - (1522.4 \text{ ₥} + 1499.2 \text{ ₥})\\ &= 178.4 \text{ ₥};\end{aligned}$$

$$\frac{b}{\sin B} = \frac{c}{\sin C}$$

$$b = c \times \frac{\sin B}{\sin C},$$ which for convenience may be stated as:

$$\text{sought side} = \text{base} \times \frac{\text{sin of the angle opposite the sought side}}{\text{sin of the angle opposite the base}};$$

substituting,

$$AC = 650 \times \frac{\sin 1499.2 \text{ ₘ}}{\sin 178.4 \text{ ₘ}}$$

From this point on, the equation may be solved by:

(1) NATURAL FUNCTIONS:

$$AC = 650 \times \frac{.99511}{.17425} = 3712 \text{ yards}$$

(2) LOGARITHMS:

Log 650	=	2.81291
Log sin 1499.2 ₘ	=	9.99787 − 10
		12.81078 − 10
Log sin 178.4 ₘ	=	9.24117 − 10
Antilog		3.56961
	=	3712 yards = AC.

(3) MILITARY SLIDE RULE.

c. Procedure. The procedure involved in the short base method of intersection includes:

(1) SELECTION OF A BASE. The base should be sufficiently long to give an angle of intersection at the desired point of 150 mils for the aiming circle or 100 mils for the transit. If the base is to be used to determine target area distances, it should be as nearly perpendicular to the direction of fire as possible so that any errors in the distances will appear in firing data as range errors rather than as deflection errors.

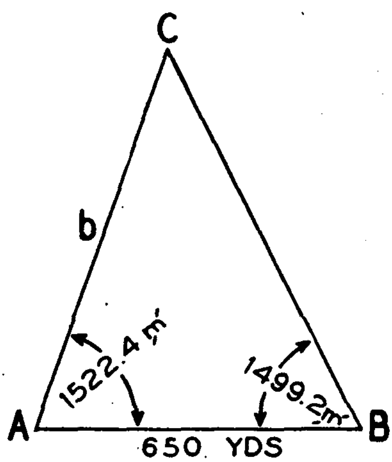

Figure 96. Solution of oblique triangle for length of a side.

(2) DETERMINATION OF THE LENGTH OF THE BASE. The length of the base may be determined by any of the methods listed in paragraph 238, except aiming circle stadia. The length of the base may also be determined by computation, using a known distance (fig. 97). Example: The

length of the base AB is desired. The distance AC is known, having been obtained either by scaling from the chart or by computing from the coordinates of points A and C. The angles at A and B are measured on the ground. The triangle can then be solved (b above) for AB. The accuracy of this method is dependent upon the accuracy with which angles at A and B are measured.

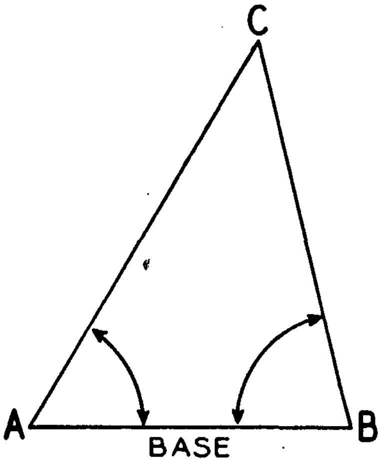

Figure 97. Computation of base length from a known distance.

(3) CHECKING THE LENGTH OF THE BASE. It is very important that the length of the base be correct, as errors in its length are magnified in the distances obtained. The length of the base should *always* be checked by one of the methods suitable for determining the length or by aiming circle stadia.

(4) MEASUREMENT OF ANGLES AT THE ENDS OF THE BASE. Angles measured at the ends of the base with an aiming circle should be cumulative. Angles with the transit should be measured direct and reversed. If the point to which the angles are read is accessible, all three angles of the triangle should be read and checked to see that their total is 3200 mils (180 degrees). If their total varies appreciably (par. 275) from 3200 mils, they should be remeasured.

242. RIGHT ANGLE BASE.

a. The right angle base method is similar in principle to the short base method; the only difference is that the distance sought is obtained by the solution of a right triangle.

b. The procedure is as follows (fig. 98):

(1) To determine the distance AB, set up an instrument at B, and lay on A. An angle of 1600 mils is turned off, and in this direction a base is laid off. With the instrument at A, the angle BAB′ is read.

(2) The distance AB is determined by the formula, $\cot A = \frac{b'}{a}$ (par. 239)

$b' = \cot A \times a.$

Example:

Assume BB′ = 100 yards and angle A = 157.5 mils. Then, AB = cot 157.5 m × 100. This equation may be solved most easily by natural

functions, since only one operation is required. Thus $AB = 6.41578 \times 100 = 641.6$ yards. By keeping the auxiliary base in even hundreds, the computation is reduced to a minimum.

c. The right angle base should be sufficiently long to make the angle subtended by the base (angle A, fig. 98) equal to or greater than 150 mils for the aiming circle or 100 mils for the transit.

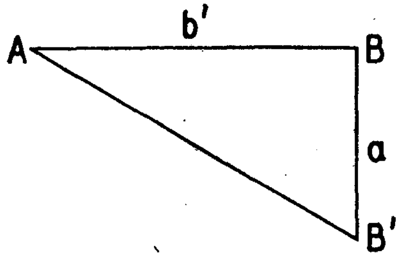

Figure 98. The right angle base.

d. The measurement of angles in the right angle base method should conform to the procedure in the measurement of angles for short base intersection (par. 241c). If only the critical angle is measured, three cumulative angles should be taken with the aiming circle or one direct and one reversed with the transit.

243. AIMING CIRCLE STADIA.

a. Aiming circle stadia is nothing more than a modification of the right angle base method of determining distance in which accuracy is sacrificed for speed.

b. The procedure for aiming circle stadia is identical with that of the right angle base with the following exceptions:

(1) Only the critical angle of the triangle is measured.

(2) The stadia base is put out at 1600 mils without the use of an instrument; this is best accomplished by lining the base in by sighting along the edges of a notebook or some other rectangular object.

(3) The requirement that the base subtend an angle of 150 mils for the aiming circle is disregarded. Reduction in the required length of the base makes its installation faster and easier.

c. The triangle may be solved exactly as it is in the right angle base method.

d. In the aiming circle stadia method, the distance is usually determined by use of the military slide rule. To stay within the capabilities of the slide it is necessary to:

(1) Keep the critical angle below 70 mils. This is accomplished by determining approximately (by estimation or pacing) the distance sought in yards. The base is then laid off a distance in feet equal to one tenth of the approximate distance sought in yards. This will give an angle of approximately 30 mils. As an example, the desired distance is approximately 300 yards. The base should be 30 feet (300/10).

(2) Solve the triangle by tangent formula (fig. 98).

$$\text{Tan A} = \frac{a}{b'} \quad \text{(par. 239)}$$

$$b' = \frac{a}{\tan A}$$

which can be readily solved with the military slide rule.

e. The aiming circle stadia method is suitable for short traverses especially in position area survey. The vertex angle should be determined by cumulative readings to the nearest tenth of a mil, and the base should be taped to the nearest tenth of a foot. The method has an accuracy of about 1 in 200.

Section III. LOCATION OF POINTS

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244. METHODS. Points may be located by traverse, by resection, by long base intersection, or by known direction and distance.

245. TRAVERSE.

a. Personnel and duties of a traverse party.

(1) A complete field artillery traverse party consists of an instrument man, two recorders and computers, two tapemen, and two rodmen. The instrument man is in charge of the party. He measures all angles and habitually paces the distance between stations as a check against gross errors in the surveyed distance. The recorders and computers maintain separate records (c below) of all angles and distances. They also compute the dx, dy, and altitude differences (par. 265) from station to station. Their computations are made independently and only the results of the computations for each station are compared. The tapemen determine horizontal distances as prescribed in paragraphs 210 and 211. Each tapeman keeps an independent record. These are checked against each other and against the paced distance. If this comparison reveals disagreements, the distance is retaped. The rodmen hold the rods (range poles) on the foresight and backsight. The front rodman should be a very capable man since he may be charged with selecting the route of the traverse.

(2) The personnel of a traverse party may be reduced by having the instrument man do his own recording and by having one of the tapemen also act as a rodman.

b. Procedure.

(1) The instrument is set up over the starting point and, with a scale reading of zero, the vertical hair is placed on the reference point

which marks the initial direction. With the upper motion, the vertical hair is turned to the second station. The angle turned is always the clockwise angle. When time is available and when the aiming circle is used, the angle should be the average of two cumulative readings; with the transit, the angle should be the result of one direct and one reverse reading. The instrument is then moved to the second station, backsighted on the first station with a scale setting of zero, and the clockwise angle to the third station is turned with the upper motion. This procedure is continued; all backsights on the previous stations are made with a scale setting of zero, and the clockwise angle is always turned. This procedure is satisfactory for use with both the aiming circle and the transit. Other traverse procedures are discussed in TM 5–235.

(2) For methods of determining the length of the legs of the traverse, see paragraph 238.

(3) Vertical angles are determined as prescribed in paragraphs 218 and 230.

c. Recording. The angles and distances determined during the traverse are recorded both in tabular form and by a sketch of the traverse. An organization should adopt a standard form and then use the adopted form habitually. Figure 99 shows a suggested form.

The traverse data form shown in figure 99 should be supplemented as needed to fit any situation. For instance, for use in a transit and transit stadia traverse, the "1st" and "2d" horizontal angles would become "direct" and "reversed" and an additional column would be added for the rod intercept. For an aiming circle stadia traverse, two columns, stadia angle and base length, would be added.

d. Computing.

(1) The differences in the X and Y coordinates for each leg are computed by the azimuth and known distance method (par. 265). These differences, taken to the nearest yard, are applied to the coordinates of the previous station so that the coordinates of each station are carried forward.

(2) Difference in altitude is obtained by the mil relation (horizontal distance times vertical angle) for an aiming circle traverse, and by trigonometric means (horizontal distance times tangent of the vertical angle) for transit traverse. The difference in altitude is computed to a tenth of a yard, and applied to the altitude of the previous station.

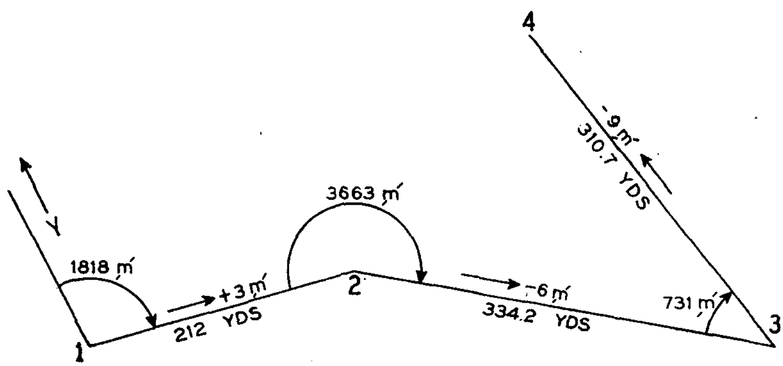
e. Plotting. The information desired from the traverse may be obtained by plotting as follows:

(1) By plotting the angles and distances directly on the firing chart from the field notes. This method will not give precise results on a chart of scale as small as 1/20,000. It is a satisfactory method if the

TRAVERSE DATA FORM

Station From-To	Horizontal Angle 1st	2d	Mean	Azimuth	Distance	Vertical Angle	X Coordinate	Y Coordinate	Altitude
Y-1				2800			20.000	40.000	500.0
1-2	1818	3636	1818	+1818	212	+3	+.209	+.038	+.6
				4618					
				-3200					
				1418			20.209	40.038	500.6
2-3	3662.4	7326	3663	+3663	334.2	-6	+.322	-.091	-1.8
				5081					
				-3200					
				1881			20.531	39.947	498.8
3-4	731	1462	731	+731	310.7	-9	-.170	+.260	-2.7
				2612					
							20.361	40.207	496.1

a
FORM



b
SKETCH

Figure 99. Suggested form and sketch for recording angles and distances of a traverse. Form may also show computation of coordinates.

traverse contains only one leg but should be used with caution for traverses of more than one leg.

(2) By plotting the angles and distances to such a scale as 1/2000, 1/5000, or 1/6667, and then plotting the resultant direction and distance on the firing chart to the proper scale (fig. 100).

If space permits, the large scale plot is made directly on the firing chart. If space does not permit, the large scale plot is made on a separate sheet and only the resulting angle (*Y*–1–4) and distance (1–4′) are plotted on the firing chart.

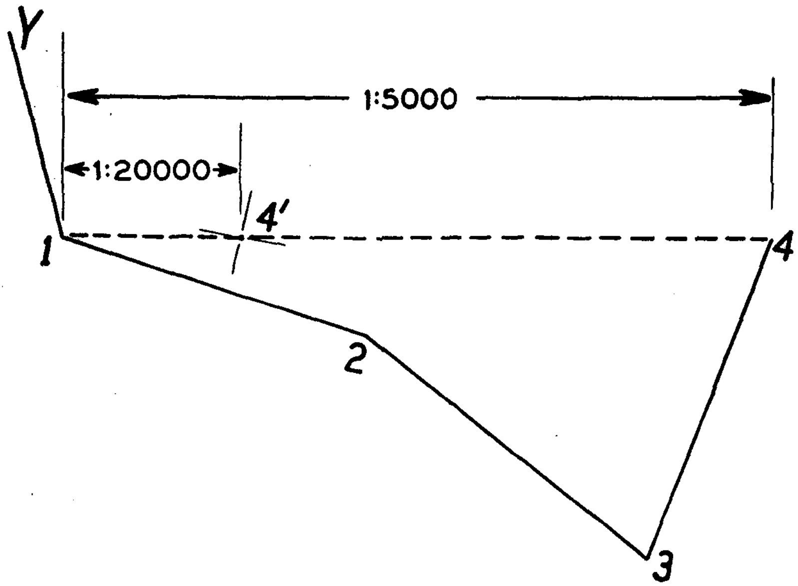


Figure 100. Traverse plotted at 1/5000 scale (solid lines). Resulting data reduced to 1/20,000 (dotted line from 1-4′). Correct direction obtained by drawing line from known point (1) to point that is sought (4). Correct (1/20,000) distance determined by measuring distance from 1 to 4 with scale at which plot is made and by replotting same distance with 1/20,000 scale.

f. Adjusting the traverse. If time permits, all traverses should be closed, because closing a traverse provides a check against blunders and permits the traverse to be adjusted. In a closed traverse, if the error of closure is more than 1 per cent of the total length of the traverse, the traverse should be repeated. If less than 1 per cent, the traverse may be adjusted as follows:

(1) In figure 101, the dotted line through points a, b, c, d, and e represents a closed traverse as actually made, beginning at and closing on A, the ground location of both a and e; ae is the error of closure.

(2) Lay off on a straight line successively the various distances ab, bc, cd, and de, representing the various legs of the traverse.

(3) From the last point on the straight line, e, draw a line ee′, equal to the error of closure, and at right angles to the straight line. Draw a straight line connecting a and e′.

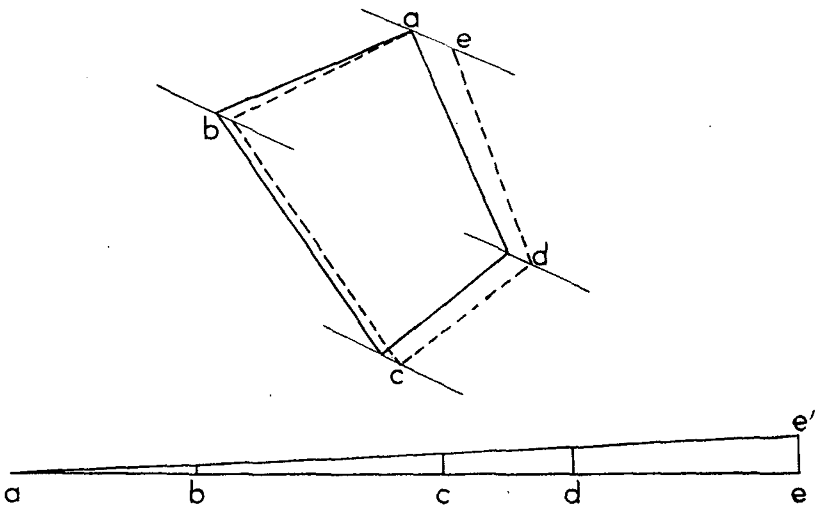


Figure 101. Adjusting the closing error.

(4) Through the points b, c, and d on the straight line ae, draw lines parallel to ee′, cutting ae′. The lengths of these short lines represent the adjustments to be made at the corresponding points of the traverse.

(5) On the traverse as plotted, draw a line through each point parallel to the error of closure ae. Lay off on these parallel lines the distances determined in (4) above. The correction is applied in the same direction on all lines. The direction is that in which the final station is moved to close the traverse.

246. RESECTION.

a. Purpose. Resection is used to locate an occupied station, given the chart and ground location of a number of unoccupied stations. Resection normally requires three or more located points.

b. Tracing paper method (fig. 102). The tracing paper method requires three (preferably four or five) distant visible points (A, B, and C), located on the chart as a, b, and c. The aiming circle is set at the station (P). The angles between the distant points are measured with the aiming circle, and plotted on transparent paper; point P is any convenient point on the paper. The rays going to A, B, and C are marked for identification only. The transparent paper is placed over the chart, and moved until each ray passes through the chart location of its respective point. The chart location of the point P is then pricked through the tracing paper at the intersection of the rays.

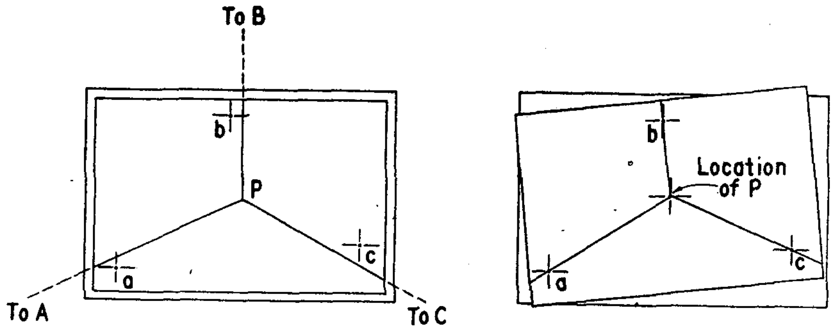


Figure 102. Tracing paper resection.

c. Back azimuth method (fig. 103).

(1) GENERAL. The back azimuth of a given direction is the azimuth plus (or minus) 3200 mils. The back azimuth method requires an accurately declinated angle measuring instrument and two (preferably three) visible points located on the map. The rays from these points through the occupied station should intersect at angles not smaller than 300 mils.

(2) PROCEDURE. Set up the declinated instrument at the point to be located and measure the *Y*-azimuth to each of the three distant points. Find the back azimuths by adding (or subtracting) 3200 mils to each *Y*-azimuth. Through each plotted point, draw a ray with the proper back azimuth. The intersection of the rays is the location of the station P.

(3) ACCURACY. The accuracy of location of the point depends upon the accuracy with which the declination constant of the instrument has been determined with respect to the chart used. This method is the only method which can be used when P is on the circumference of the circle passing through A, B, and C.

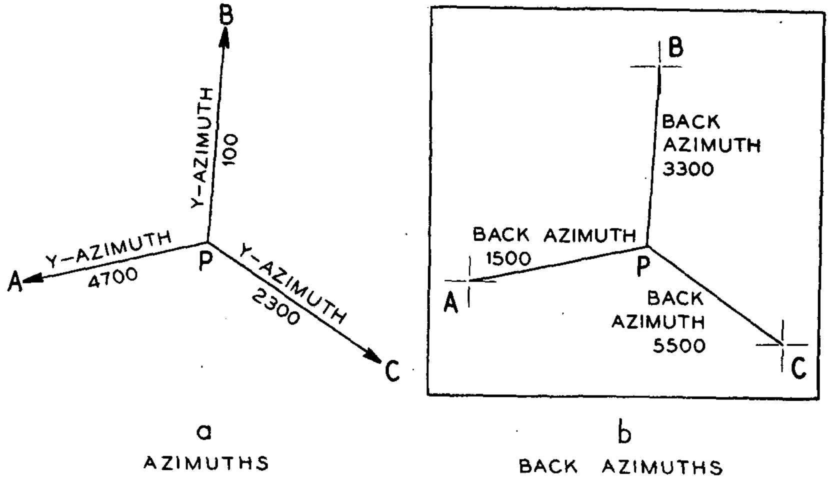


Figure 103. Back azimuth resection.

247. LONG BASE INTERSECTION.

a. Advantages and disadvantages. When the angle of intersection of the rays from the ends of a base to a desired point is between 500 and 2700 mils the base is termed long base; if the angle of intersection is less than 500 mils the base is termed short base. The advantages of long base intersection as compared with short base intersection are that the results may be determined by plotting and that, if computed, the results are usually more accurate, since errors in angular measurements result in smaller errors in the final result. The disadvantages of long base intersection are the difficulty of identifying points from widely separated stations, and the difficulty of finding and locating points that will give angles of intersection of not less than 500 mils.

b. Procedure.

(1) The location of points by long base intersection is illustrated by figures 104 through 107. Figures 104, 105, and 106 illustrate the methods of locating points other than an occupied point of the base. Angles A and B are clockwise angles measured on the ground and reported as instrument readings. Angles A′ and B′ are plotted equal to angles A and B. Figure 107 illustrates the method of locating one of the two occupied points of the base. Angles A and B are measured by instument on the ground. Angles A′ and C are plotted on the chart; angle C is computed from angles A and B.

(2) Distances may be determined by computation as in paragraph 241, and the point located as in paragraph 248.

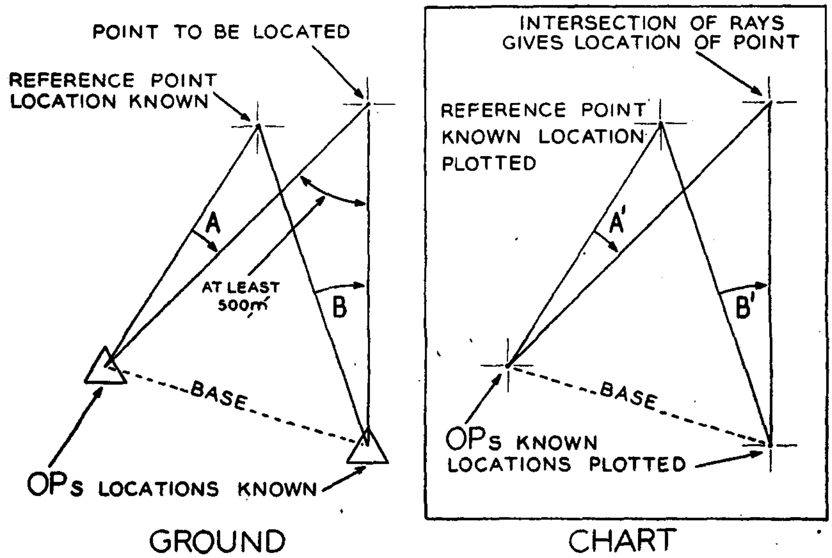


Figure 104. Location of point near reference point by long base intersection. This method produces the most accurate results.

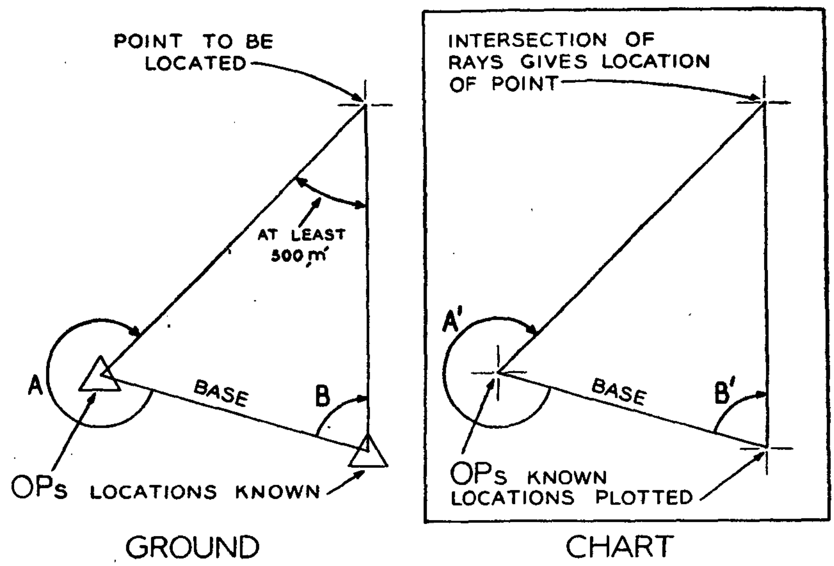


Figure 105. Use of observation posts as reference points to locate a point by long base intersection. This method is less accurate than that illustrated in figure 104.

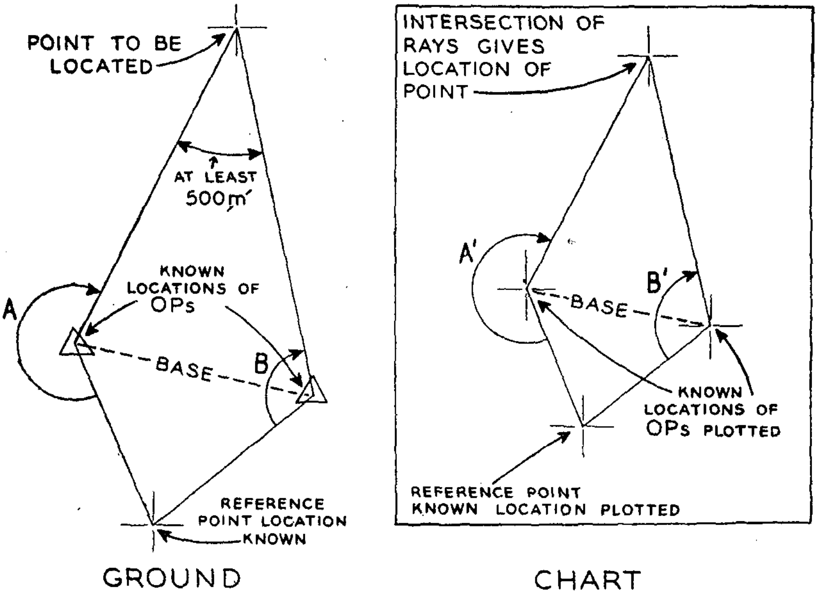


Figure 106. Location of a point distant from reference point by long base intersection. This method is least accurate.

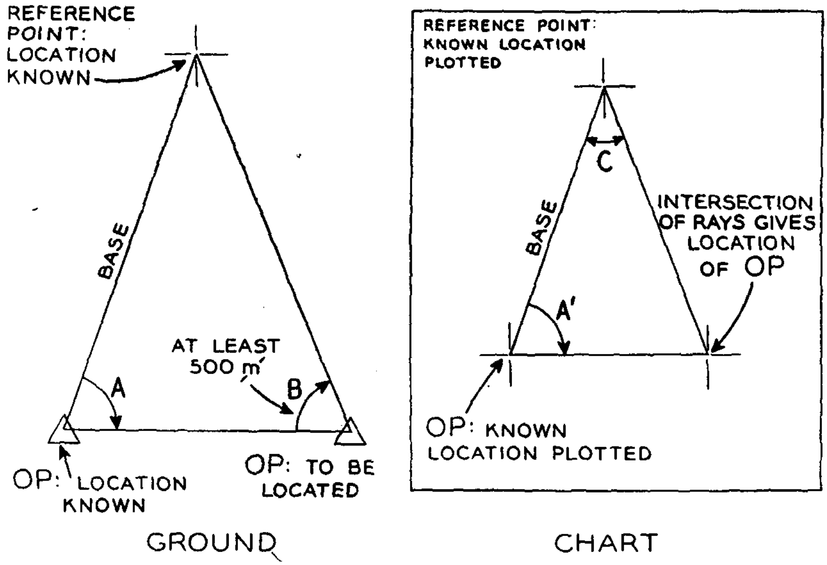


Figure 107. Location of one of the two occupied points of a base by long base intersection.

248. KNOWN DISTANCE AND DIRECTION.

a. The location of a point by a known distance and direction in itself involves no ground survey but is a method of obtaining the desired results from ground survey that has already been completed.

b. To locate a point by this method, the following information must be available:

(1) The location of one point.

(2) A known direction from the point of known location.

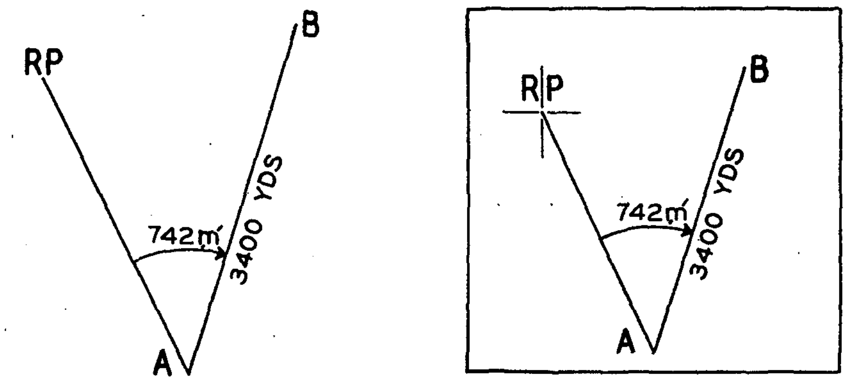
(3) The angle from the known line of direction to the point sought.

(4) The distance from the known point to the point sought.

c. When the information above is available, the location of the sought point may be determined by:

(1) Computation of differences in the coordinates of the known point and the point sought (par. 265).

(2) By polar plotting (fig. 108).



a GROUND SURVEY

b CHART

LEGEND

A = known point

A–RP = known direction

B = sought point

742 mils = measured angle giving direction

3400 yards = known distance

Figure 108. Plotting a point by computed range and measured direction.

d. This method of locating points used in combination with short base intersection to determine the distance is in most cases preferable to long base intersection. This is true because the short base as compared with the long base has these advantages: points are more easily identified from both ends of the base; terrain is usually more favorable for establishing a short base; communication between ends of the base is simpler; accuracy of results is usually greater.

Section IV. THE TARGET AREA BASE

249. GENERAL. The target area base is merely a slight modification of the method of short base intersection. It is designed for rapid target location. For most effective use, wire communication should be provided between the ends of the base.

250. SELECTION; DETERMINATION AND CHECK OF LENGTH. The same principles apply to the target area base as apply to the short base (par. 241c).

251. INSTRUMENTS. The target area base requires two instruments, one at each end of the base. Both instruments should read in mils or both should read in degrees. A combination of a mil instrument and a degree instrument is undesirable because of time consumed by, and possible error in, the necessary conversion.

252. SETTING UP THE BASE. The ends of the base are designated as point A and point S. Point A is the controlling end of the base. The instrument operators at A and S orient their instruments so that the 0–3200 lines coincide with the line SA, assuming S is on the right (fig. 109a); if S is on the left, they will coincide with AS (fig. 109b).

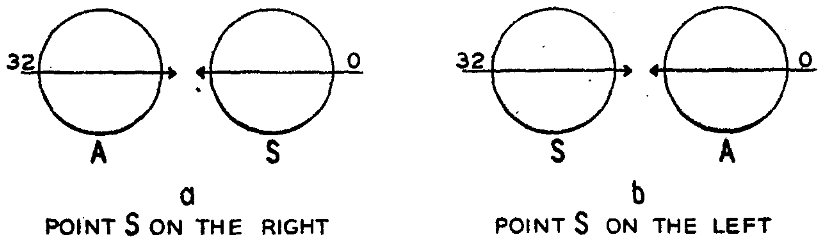
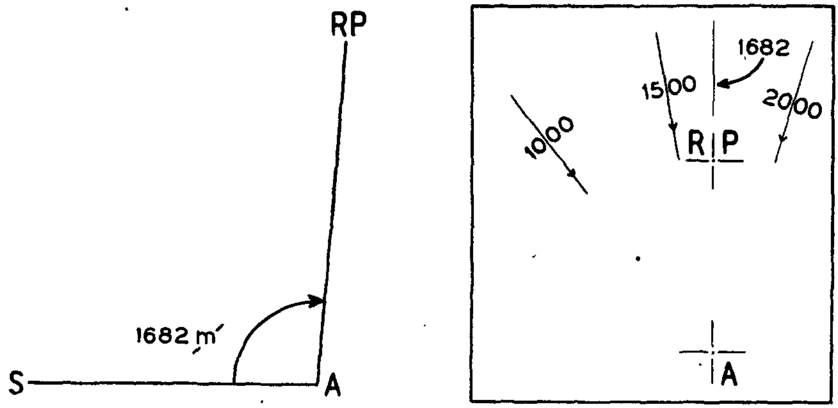


Figure 109. Orienting instruments on a target area base. Arrows indicate line of sighting and numerals the correct setting on each instrument.

When oriented, both instruments measure clockwise angles from the line SA in figure 109a or from the line AS in figure 109b. The orientation of instruments must be checked frequently. Since the base is short, a distance reference point insures greater accuracy. Each observer should pick a well defined point and accurately determine his instrument reading to it. Thereafter, to check orientation, he sights on the reference point and checks readings.

253. ORIENTATION ON THE FIRING CHART (fig. 110). The location of point A is determined and plotted on the chart. Point S is not plotted on the chart. Point A reports to fire-direction center the instrument reading to point (preferably base point, check point, or reference point) from which direction originated for orientation of the pieces. By this means, the basis for direction used in the orientaton of the pieces and for locations in the target area is the same, thus tying together the targets and pieces for direction. (If the chart location of no point visible from A is known, the ground location of some visible point is determined by survey, and its coordinates are computed based on the control at point A.) Orientation of the base on the chart is accomplished as follows: with the vertex of a range-deflection fan at point A, and one edge passing through the point for which the instrument reading is given, a short reference line is drawn along the edge of the fan so that it intercepts one of the mil arcs. This line is labeled with the given instrument reading. Using this line as a basis, other reference lines are drawn for instrument readings of multiples of 500 mils, and labeled with their respective instrument readings. Enough of these lines are placed on the chart to cover the entire target area.



a
GROUND ORIENTATION

b
CHART ORIENTATION

Figure 110. Orientation of target area base on chart.

254. SOLUTION OF THE TRIANGLE (fig. 111). With the instruments oriented as they are, the instrument reading to a sought point will be angle a from the right end of the base and angle d from the left end. The distances sought are computed by solution of the following formulas:

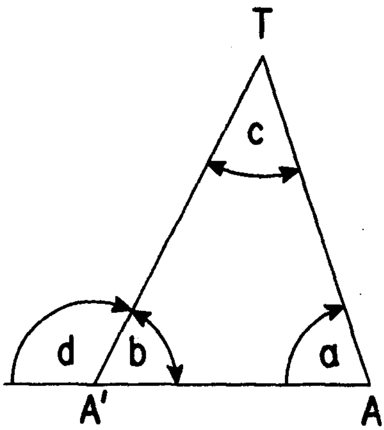


Figure 111. The short base triangle.

a. With A on the right, solving for AT

$$AT = \text{base} \times \frac{\sin d}{\sin c}$$

b. With A on the left, solving for A'T

$$A'T = \text{base} \times \frac{\sin a}{\sin c}$$

c. The formulas above are based on the formulas for solution of the oblique triangle (par. 240) and the facts:

$$c = d - a$$
$$\sin d = \sin b$$

255. LOCATION OF THE TARGET. The entire procedure is illustrated by the following example: point A on the right; base length 625 yards; instrument readings: point A, 1520.2 ₥; point S, 1680.3 ₥. Substituting in formulas:

$$c = 1680.3 - 1520.2 = 160.1$$

$$AT = 625 \times \frac{\sin 1680.3\ ₥}{\sin 160.1\ ₥} = 3980 \text{ yards}$$

This equation may be solved by natural functions, logarithms, or the military slide rule. For speed the last is preferable to the first two.

The instrument operator at point A rounds off the distance to the nearest 10 yards, and reports to fire-direction center, "Instrument reading 1520 ₥, distance 3980, vertical angle —2" (measured from point A to target).

The horizontal control operator and vertical control operator plot the target by using reference lines on the chart (par. 253) and the reported distance. The vertical control operator determines the altitude of the target by the range and the angle of site.

256. MEASUREMENT OF ANGLES AT ENDS OF THE BASE.

a. For the location of base points and check points, three cumulative readings should be taken at each end of the base. For targets, multiple readings are taken to prevent blunders.

b. When a target is selected at point A, an approximate instrument reading can be given to point S by applying the angle of intersection at the target to the instrument reading at point A. The approximate angle of intersection can be computed by the formula:

$$\sin \text{ angle of intersection} = \frac{\text{base}}{\text{Estimated target distance}} \times \sin \text{ instrument reading at point A.}$$

This approximate instrument reading normally will place the target in the field of view of the instrument at point S, making it easier to identify the target by terrain description. The estimated target distance in the formula above may be obtained with a range finder calibrated for a known target area distance.

c. The operators must strive to lay their instruments not only on the same target but also on the same identical point of the target.

Section V. DETERMINATION AND TRANSMISSION OF DIRECTION

257. DETERMINATION OF DIRECTION. Direction may be determined by assumption, measurement with an instrument equipped with a magnetic needle (par. 223), measurement on a map or photo (par. 186), computation from coordinatese of two points (par. 263), or measurement by astronomic observations. In heavily wooded flat terrain or

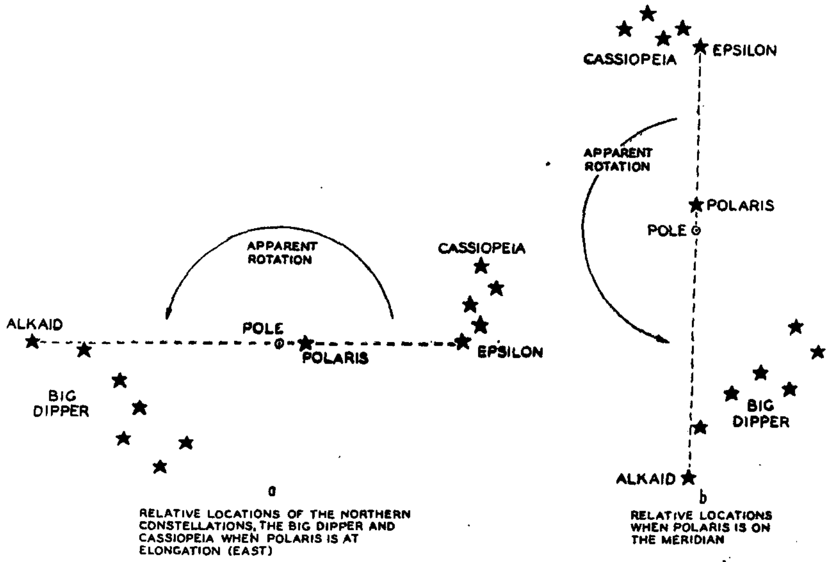


Figure 112. Polaris at eastern elongation and upper culmination.

in terrain where exceptionally long shots are necessary, the liaison type plane may be used to facilitate survey.

258. ASTRONOMIC METHODS.

a. General. True north may be determined by an observation on Polaris, as explained below. Other and more precise methods may be found in TM 5-235.

b. Procedure in determining true north by measurements from Polaris.

(1) An instrument is set up on the line whose true azimuth is to be determined. The instrument is zeroed on Polaris and the clockwise angle to the line is determined, establishing the Polaris azimuth of the line. Figure 112 shows relative positions of Polaris, the pole, the star Epsilon in Cassiopeia, and the star Alkaid in the Big Dipper.

It is evident from figure 112 that the Polaris azimuth is the same as the true azimuth only when Polaris is on the meridian, and that the variation is greatest when Polaris is at elongation. The true azimuth of a line is obtained by determining the true azimuth of Polaris at the time of observation by use of the Polarmeter, Mark I, or by determining the variation between the Polaris azimuth and the true azimuth by using constellations in the vicinity of Polaris.

(2) The variation between Polaris azimuth and true azimuth is determined as follows (fig. 113).

At the instant the instrument is laid on Polaris, determine the angle at E (Epsilon) or P (Polaris). To measure the angle, pivot a plumb bob in the center of a protractor. Hold the protractor vertical, straight edge up, so that Polaris and Epsilon, or Polaris and Alkaid, are coincident with the straight edge of the protractor. The plumb bob string is now parallel to one side of the angle and the straight edge is parallel to the other. The value of the angle may be read on the protractor where the string crosses the circular edge. Multiply the sine of this angle by the elongation as given in figure 114. The result is the sought variation at the instant of observation.

Greater accuracy is obtained if the observation is made when Alkaid is near its easterly or westerly elongation. The greatest error occurs when Alkaid is directly above or below Polaris, because the alinement of Alkaid, the pole, and Polaris is not exact. The error, however, is small and does not exceed 1 mil (3 3/8 feet) for positions south of latitude 76° N, and, when using Epsilon, for positions south of latitude 53° N.

When the variation has been determined, it is applied to the clockwise angle from Polaris to the line whose true azimuth is sought.

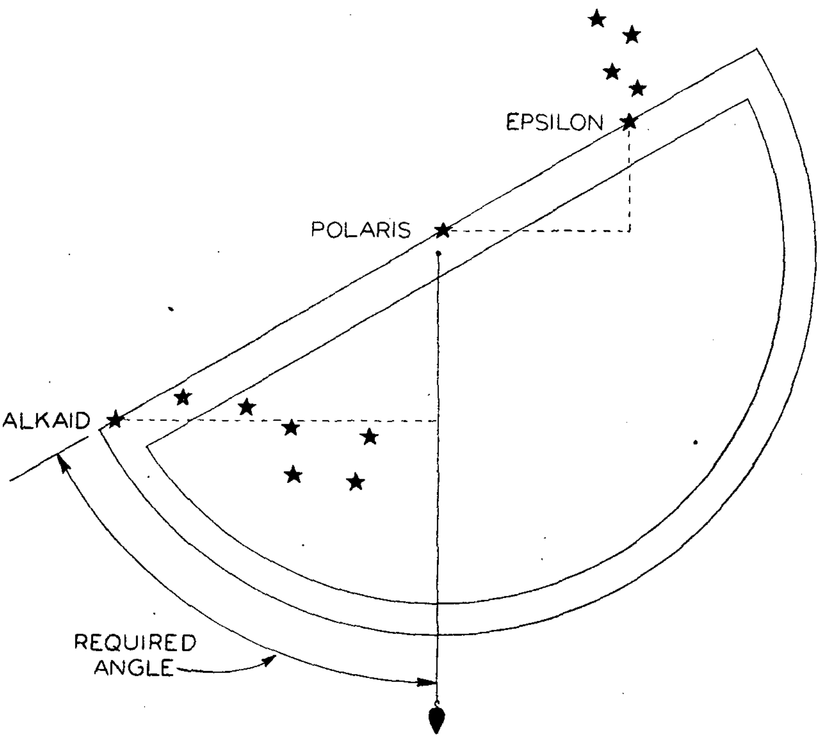


Figure 113. Determination of azimuth from Polaris.

Whether to add or subtract the variation can be determined by the location of Alkaid. The true pole is always on the same side of Polaris as Alkaid.

(3) The Polarmeter, Mark I, is an aid for determining the true azimuth of Polaris at any place between latitude 10° N and 60° N. Complete instructions regarding the mechanics of operation are part of the instrument itself. The observer's watch must be in agreement with some standard time, and the longitude as well as the latitude of the station occupied must be known; map values are satisfactory.

After true azimuth of Polaris has been determined, the variation between true and Polaris azimuths is computed and applied as described in (2) above to obtain the true azimuth of the line.

Lat.	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
25°	1 6.1	1 5.7	1 5.3	1 5.0	1 4.6	1 4.2	1 3.9	1 3.5	1 3.1	1 2.8
26	6.6	6.3	5.9	5.5	5.1	4.8	4.4	4.0	3.7	3.3
27	7.2	6.8	6.5	6.1	5.7	5.3	5.0	4.6	4.2	3.8
28	7.8	7.4	7.1	6.7	6.3	5.9	5.6	5.2	4.8	4.4
29	8.5	8.1	7.7	7.3	6.9	6.5	6.2	5.8	5.4	5.0
30	9.1	8.8	8.4	8.0	7.6	7.2	6.8	6.4	6.1	5.7
31	9.9	9.5	9.1	8.7	8.3	7.9	7.5	7.1	6.7	6.4
32	10.6	10.2	9.8	9.4	9.0	8.6	8.2	7.8	7.5	7.1
33	11.4	11.0	10.6	10.2	9.8	9.4	9.0	8.6	8.2	7.8
34	12.2	11.8	11.4	11.0	10.6	10.2	9.8	9.4	9.0	8.6
35	13.1	12.7	12.3	11.9	11.5	11.1	10.6	10.2	9.8	9.4
36	14.0	13.6	13.2	12.8	12.4	11.9	11.5	11.1	10.7	10.3
37	15.0	14.6	14.1	13.7	13.3	12.9	12.5	12.0	11.6	11.2
38	16.0	15.6	15.1	14.7	14.3	13.9	13.4	13.0	12.6	12.2
39	17.0	16.6	16.2	15.8	15.3	14.9	14.5	14.0	13.6	13.2
40	18.2	17.7	17.3	16.9	16.4	16.0	15.6	15.1	14.7	14.2
41	19.3	18.9	18.5	18.0	17.6	17.1	16.7	16.2	15.8	15.4
42	20.6	20.1	19.7	19.2	18.8	18.3	17.9	17.4	17.0	16.5
43	21.9	21.4	21.0	20.5	20.0	19.6	19.1	18.7	18.2	17.8
44	23.2	22.8	22.3	21.9	21.4	20.9	20.5	20.0	19.5	19.1
45	24.7	24.2	23.7	23.3	22.8	22.3	21.8	21.4	20.9	20.4
46	26.2	25.7	25.2	24.8	24.3	23.8	23.3	22.9	22.4	21.9
47	27.8	27.3	26.8	26.3	25.8	25.3	24.9	24.4	23.9	23.4
48	29.5	29.0	28.5	28.0	27.5	27.0	26.5	26.0	25.5	25.0
49	31.3	30.8	30.3	29.8	29.2	28.7	28.2	27.7	27.2	26.7
50	1 33.2	1 32.6	1 32.1	1 31.6	1 31.1	1 30.6	1 30.0	1 29.5	1 29.0	1 28.5

Corrections for middle of months

For middle of—	Correction
Jan	−0.5
Feb	−0.4
Mar	−0.3
Apr	−0.1
May	+0.1
June	+0.2
July	+0.2
Aug	+0.1
Sept	−0.1
Oct	−0.3
Nov	−0.6
Dec	−0.8

These data may be secured annually from the current Nautical Ephemeris or other similar source.

Figure 114. Azimuths of Polaris at elongation for the years 1945 to 1954. (Computed by the United States Naval Observatory.)

259. TRANSMISSION OF DIRECTION. Direction may be transmitted by:

a. Measurement of clockwise angles on the ground. The principal use of this method is to transmit relative azimuth to the legs of a traverse. A procedure for establishing the relative azimuths of two lines after the clockwise angle between the lines has been measured is shown below (fig. 115):

Azimuth A to B =	0 ₥
Add clockwise angle	3720 ₥
Azimuth A — Sta 1	3720 ₥
Add clockwise angle	2694 ₥
	6414 ₥
Subtract	3200 ₥
Azimuth Sta 1 — Sta 2	3214 ₥
Add clockwise angle	4583 ₥
	7797 ₥
Subtract	3200 ₥
Azimuth Sta 2 — Sta 3	4597 ₥
Add clockwise angle	5312 ₥
	9909 ₥
Subtract	3200 ₥
(greater than 6400,	6709 ₥
so subtract)	6400 ₥
Azimuth Sta 3 — Sta 4	309 ₥

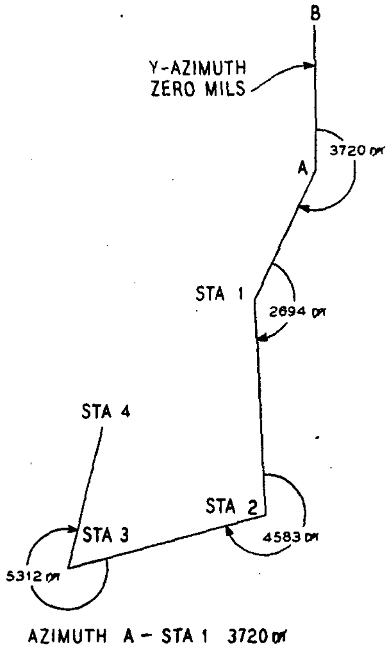


Figure 115. Computing azimuths from clockwise angles.

This method is especially good because the same operations are performed in the same order for each leg.

b. Measurement of angles on a chart. This method is illustrated by the following example (fig. 116): The azimuth of the line A-BP has been determined to be 6240 mils. The azimuth of the line G-BP is desired. The angle A-BP-G is measured on the chart as 625 mils. By applying this angle to the known azimuth (6240 ₥ + 625 ₥), the azimuth of the G-BP line is found to be 465 mils.

c. Establishing relative directions by astronomic observations. These relative directions are established in the following ways:

(1) By determining by observations on Polaris the true azimuths of the lines whose directions are sought (par. 258).

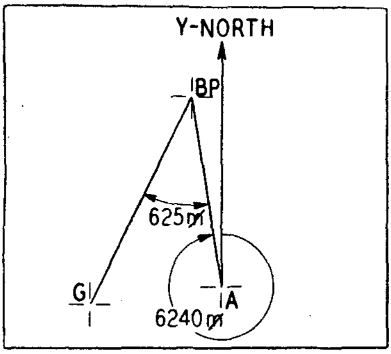


Figure 116. Transmission of of direction by measurement of chart angles.

(2) By simultaneous observations on any celestial body from each of the lines whose directions are sought.

(*a*) This method is illustrated by the following example (fig. 117): The azimuth of the line AB has been determined to be 5035 mils. The azimuth of CD is desired. Simultaneous readings are taken on Sirius from points A and C, with results as shown, establishing the relative direction of the two lines. The azimuth of CD can now be computed: *5035 m̸ — 1080 m̸ = 3955 m̸.*

(*b*) The advantage of simultaneous observations is that no computations are required. Its disadvantage is the prearrangement necessary to insure that all observations are made at the same time. As a check against mistakes and to insure satisfactory results if one observation fails, the simultaneous observations usually should be made three separate times at prescribed hours.

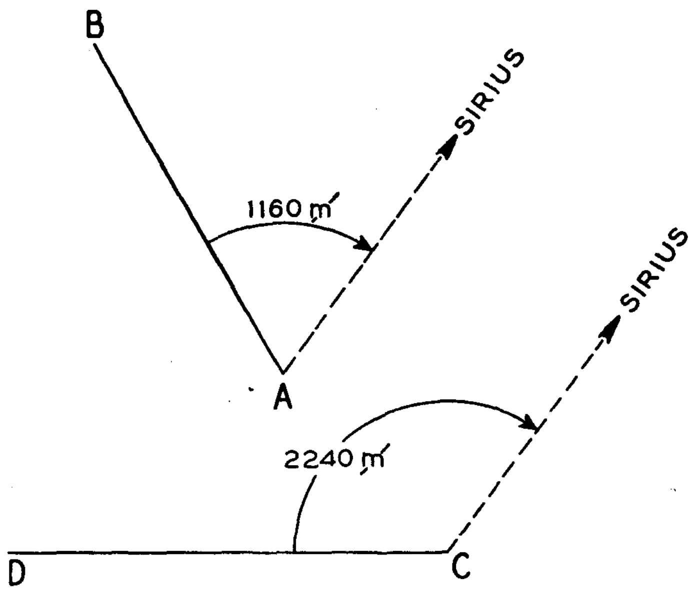


Figure 117. Transmission of direction by simultaneous observations.

Section VI. SURVEY COOPERATION WITH OBSERVATION BATTALION UNITS

260. CONTROL FURNISHED.

a. When a unit of the observation battalion works in coordination with a division, it establishes the sound and flash bases necessary to accomplish its mission. These bases are established in a manner that facilitates the ready expansion of the system upon the arrival of the remainder of the observation battalion.

b. The unit establishes its bases on the same control as division. For details see FM 6–120.

Section VII. EXTENSION OF CONTROL

261. NEED FOR EXTENSION OF CONTROL.

a. Control established in one position is extended to new positions in order to:

(1) Make possible the continued massing of fires during displacement by echelon.

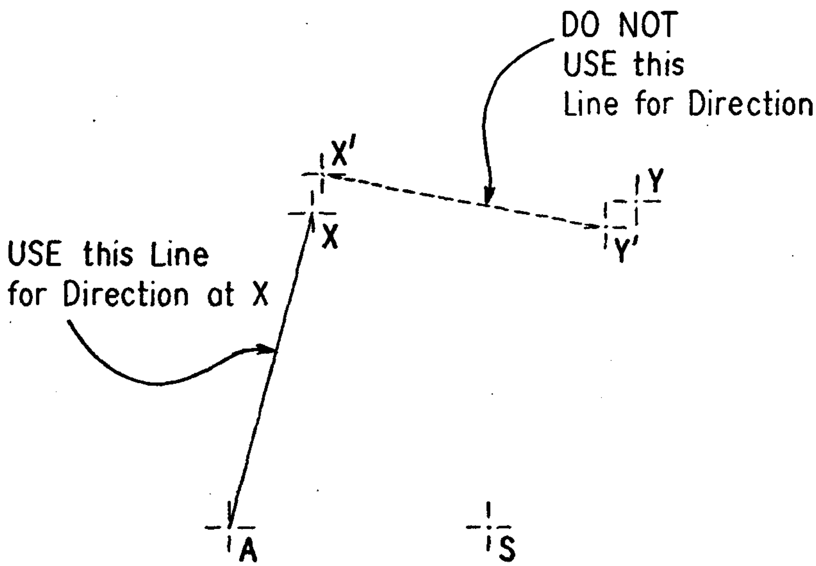
(2) Make possible the use of any information on the charts used in the old position that might be of value in the new position.

(3) Provide a means of establishing common control for the division or corps in the new position.

(4) Make use of the control that is inherent in the available maps of the new area.

b. The extension of complete control normally is necessary only when a grid sheet is the firing chart; the data furnished by extension of control are wholly provided by the battle map and partially provided by the photomap when they are used as the firing chart. Control may also be extended or supplemented by use of the fire control data sheet (par. 199c). Horizontal data afforded by the photomap must be supplemented by vertical control. Control may also be extended to supplement information afforded by the battle map or to check the accuracy of either the battle map or of the photomap.

262. EXTENDING CONTROL. The extension of control should provide the coordinates and altitude of a point, and a line of direction from the point in the new area of each battalion. Extension of control is initiated by all survey echelons. It is normally accomplished by traverse, short base intersection, or long base intersection. Normal errors in location of points by intersection, although not large enough to affect materially horizontal control in the new area, may cause considerable error in the direction between two points located by intersection. For this reason, when control is extended by intersection, it is desirable that the direction be furnished as shown in figure 118.



LEGEND

A is the point from which the survey directions to X and Y were determined.

X and Y are true locations.

X' and Y' are chart locations.

Figure 118. Extension of control.

CHAPTER 6
SURVEY COMPUTATIONS

263. CALCULATION OF Y-AZIMUTHS FROM COORDINATES. *Example.* The coordinates of two points are known; to find the *Y*-azimuth of the line joining them (fig. 119):

By inspection, the *Y*-azimuth of AB is equal to 1600 mils plus angle A. To solve for angle A: find the difference in the *X*-coordinates and the difference in the *Y*-coordinates of the two points, then determine the angle using either the tan or cot function.

Point A (815.475 — 1267.430)
Point B (818.140 — 1266.590)

$$\begin{array}{r} 818.140 \\ 815.475 \\ \hline 2{,}665 = \text{dx} \end{array}$$

$$\begin{array}{r} 1267.430 \\ 1266.590 \\ \hline 840 = \text{dy} \end{array}$$

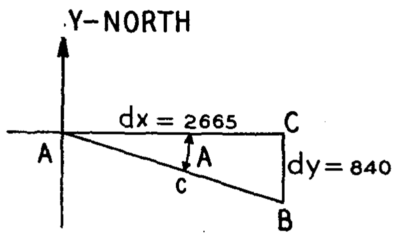


Figure 119. Calculation of distances and Y-azimuths.

a. Tan function:

$$\text{Tan A} = \frac{\text{dy}}{\text{dx}} = \frac{840}{2665} \quad \text{(par. 239)}$$

$$\begin{aligned} \text{Log tan A} &= \log 840 - \log 2665 \\ \text{Log } 840 &= 2.92428 \\ \text{Log } 2665 &= 3.42570 \\ \hline \text{Log tan A} &= 9.49858 - 10 \\ \text{A} &= 311 \text{ ㎖} \end{aligned}$$

b. Cot function:

$$\text{Cot A} = \frac{\text{dx}}{\text{dy}} = \frac{2665}{840} \quad \text{(par. 239)}$$

$$
\begin{aligned}
\text{Log cot A} &= \log 2665 - \log 840 \\
\text{Log } 2665 &= 3.42570 \\
\text{Log } 840 &= 2.92428 \\
\hline
\text{Log cot A} &= .50142 \\
\text{A} &= 311 \text{ ₥}
\end{aligned}
$$

Y-azimuth AB = 1600 ₥ + 311 ₥ = 1911 ₥. Natural functions can be used to solve either the tangent or cotangent formula, with the same results.

264. CALCULATION OF DISTANCES FROM COORDINATES.

a. For example, the coordinates of two points are known; to find the distance between the two points (fig. 119):

(1) COMPUTATION USING COSINES:

$$
\begin{aligned}
\text{Cos A} &= \frac{dx}{c} \quad \text{(par. 239)} \\
c &= \frac{dx}{\cos A} \\
c &= \frac{2665}{\cos 311 \text{ ₥}}, \quad \text{(angle A computed as in par. 263)} \\
\text{Log c} &= \log 2665 - \log \cos 311 \text{ ₥} \\
\text{Log } 2665 &= 3.42570 \\
\text{Log cos } 311 \text{ ₥} &= 9.97943 - 10 \\
\hline
\text{Log c} &= 3.44627 \\
c &= 2794.3 \text{ yards}
\end{aligned}
$$

(2) COMPUTATION USING SINES:

$$
\begin{aligned}
\text{Sin A} &= \frac{dy}{c} \quad \text{(par. 239)} \\
c &= \frac{dy}{\sin A} \\
c &= \frac{840}{\sin 311 \text{ ₥}}, \quad \text{(angle A computed as in par. 263)} \\
\text{Log c} &= \log 840 - \log \sin 311 \text{ ₥} \\
\text{Log } 840 &= 2.92428 \\
\text{Log sin } 311 \text{ ₥} &= 9.47799 - 10 \\
\hline
\text{Log c} &= 3.44629 \\
c &= 2794.4 \text{ yards}
\end{aligned}
$$

b. Either the sine or cosine formula may be solved using natural functions, with the same results. The distance also may be determined by the formula $c = \sqrt{dx^2 + dy^2}$ (par. 239).

265. CALCULATION OF COORDINATES.

a. The coordinates of a point, and the *Y*-azimuth and distance from this point to a second point are known; to calculate the coordinates of the second point (fig. 120):

Angle A = 3200 mils − 2625 mils = 575 mils

$$\sin 575 \text{ mils} = \frac{dx}{4215} \quad \text{(par. 239)}$$

$$dx = 4215 \times \sin 575 \text{ mils}$$

$$\begin{aligned} \text{Log } 4215 &= 3.62480 \\ \text{Log sin } 575 \text{ mils} &= 9.72835 - 10 \\ \hline \text{Log dx} &= 3.35315 \\ dx &= 2255 \text{ yards} \end{aligned}$$

$$\cos 575 \text{ mils} = \frac{dy}{4215} \quad \text{(par. 239)}$$

$$dy = 4215 \times \cos 575 \text{ mils}$$

$$\begin{aligned} \text{Log } 4215 &= 3.62480 \\ \text{Log cos } 575 \text{ mils} &= 9.92678 - 10 \\ \hline \text{Log dy} &= 3.55158 \\ dy &= 3561 \text{ yards} \end{aligned}$$

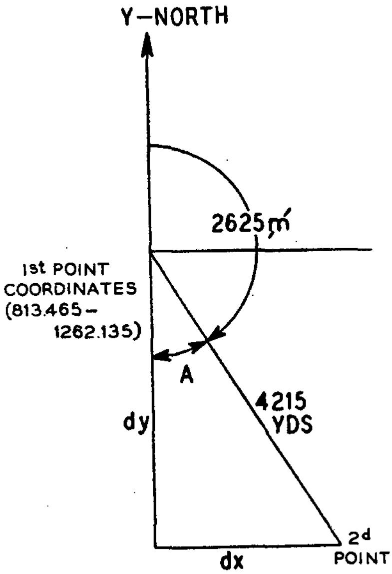


Figure 120. Calculation of coordinates.

Hence, the coordinates of the second point are:

$$X = 813.465 + 2.255 = 815.720$$
$$Y = 1262.135 - 3.561 = 1258.574$$

A rough sketch like the one above (fig. 120) will aid in solving for dx and dy will prevent their application in the wrong sign.

b. A standard form for computation of coordinates is shown in FM 6–120. This form is very useful in training new survey personnel.

c. Coordinates may be computed rapidly with the mathematical slide of the graphical firing table, a method which is particularly adaptable to computing aiming circle traverses.

266. DETERMINATION OF BASE ANGLES. Base angles may be determined by plotting the base line and the orienting line on the chart and by measuring the resulting angle of intersection; base angles may also be computed. Because of the inherent inaccuracy of plotting, computing is the preferred method. Base angles may be computed by the azimuth method or by the polygon method.

267. COMPUTATION OF BASE ANGLES; AZIMUTH METHOD.

a. In this method the base angle is determined by subtracting the azimuth of the base line from the azimuth of the orienting line.

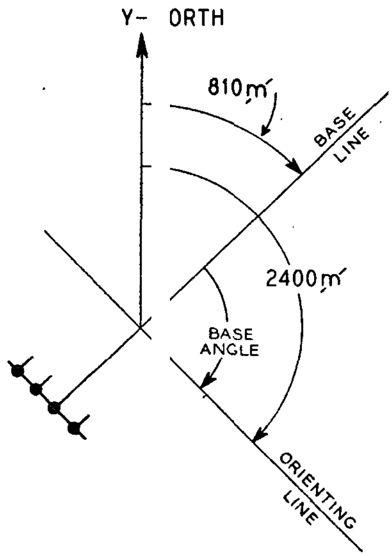


Figure 121 Computation of base angle by azimuths.

Example (fig. 121):

Azimuth of orienting line	=	2400 ₥
Azimuth of base line	=	810 ₥
Base angle	=	1590 ₥

b. If the azimuth of the base line is greater than the azimuth of the orienting line, 6400 mils is added to the azimuth of the orienting line. *Example*:

Azimuth of orienting line = 210 ₥
Azimuth of base line = 6219 ₥
Base angle = (210 ₥ + 6400 ₥) − 6219 ₥ = 391 ₥

c. If the result of the subtraction of the base line azimuth from the orienting line azimuth is greater than 3200 mils, 3200 mils is subtracted from it. *Example*:

Azimuth of orienting line	=	6143 ₥
Azimuth of base line	=	138 ₥
		6005 ₥
		−3200 ₥
Base angle	=	2805 ₥

d. The azimuth of the base line is usually measured from the chart; however, it may be computed from the coordinates of the base piece and base point. The azimuth of the orienting line may be determined by measurement with an instrument, measurement from a map or photo, or by computation from coordinates.

268. COMPUTATION OF BASE ANGLES; POLYGON METHOD.

This method is based on the theorem that the sum of the interior angles of any polygon equals $3200 \times (n - 2)$ mils, in which n is the number of sides of the polygon. This method is illustrated by the following example: A rough sketch of the traverse and the other elements of the survey (fig. 122) should be drawn. This sketch supplemented by a

grid line or by a line drawn on the chart will form a polygon in which all the interior angles except one are known. The unknown angle can then be computed using the theorem (the sum of the interior angles of a polygon = 3200 × (*n* — 2) mils). In figure 122, angles 1, 2, 3, and 4 are known from instrument measurements made during the traverse. Angle 5 is measured from the chart. The polygon has six sides, then angle X = 3200 × (6 — 2) — (angles 1 + 2 + 3 + 4 + 5). Base angle = 3200 — X.

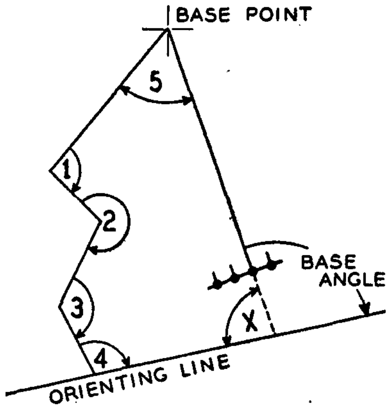


Figure 122. Computation of base angles by polygon method.

269. COMPUTATION OF REMAINING BASE ANGLES.

a. If a single orienting line is used for the entire battalion, the base angles of the remaining batteries can be determined by merely applying the base point offsets to the first base angle computed.

Example: In figure 123, the base angle B has been determined as previously explained. Angles 1 and 2 are measured from the chart. Base angle A is equal to angle B plus angle 1. Base angle C is equal to angle B minus angle 2.

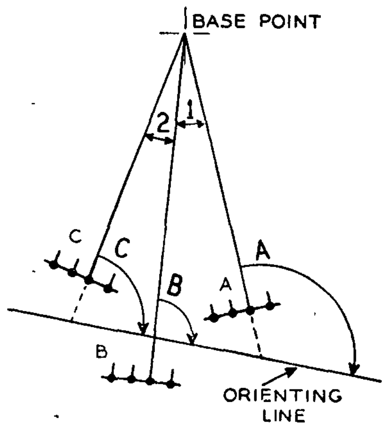


Figure 123. Computation of remaining base angles, when a single orienting line is used for the battalion.

b. If the batteries are so situated that more than one orienting line is required, the computation of the remaining base angles involves more operations.

Example: In figure 124, the base angle B has been determined. Base angle C is sought.

(1) BY AZIMUTH METHODS. The azimuth of the orienting line of Battery C is known by traverse through angles 1 and 2. The azimuth of the Battery C base line is measured from the chart. The base angle is equal to the difference of the two azimuths.

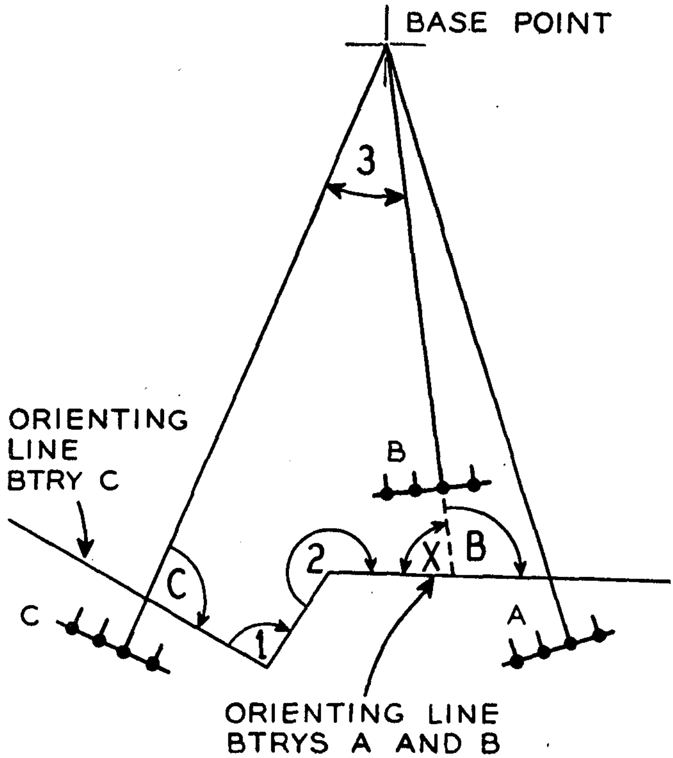


Figure 124. Computation of remaining base angles, when more than one orienting line is required.

(2) BY POLYGON METHOD. Angle X = 3200 minus angle B. Angles 1 and 2 are determined by traverse. Angle 3 is measured from the chart. Base angle C is equal to 3200 × (5 — 2) — (angles 1 + 2 + X + 3).

CHAPTER 7
SURVEY ACCURACY
Section I. STANDARDS

270. GENERAL. The precision with which field artillery survey operations must be performed is governed by the allowable error which may exist in determining the chart location of gun and target. Since the effect which the survey operations of the various field artillery echelons have on this determination varies with the complexity of the particular survey problem, no fixed rule governing the precision to be attained by each echelon can be formulated. However as a basis for organization and training the standards listed below are put forward as being those required in the normal situation.

271. BATTALION. The following are desired standards of accuracy:

a. 1 in 1000 for position area survey (1 in 500 for light artillery).

b. 1 in 1000 for connection survey (1 in 500 for light artillery).

c. 1 in 1000 for target area base length.

d. 1 in 500 for location of targets.

e. Direction imparted to guns correct within 1 mil.

272. HIGHER ECHELONS. The following are desired standards of accuracy:

a. Division artillery.

(1) 1 in 1000 for points in position area.

(2) 1 in 500 for points in target area.

(3) Direction furnished to lower echelons correct within 1 mil.

b. Corps observation battalion.

(1) 1 in 3000 for all points.

(2) Direction furnished to lower echelons correct within 20 seconds.

c. Engineers, corps, or army. Accuracy as prescribed for grid survey in TM 5–235.

273. RULES FOR ACCURACY. The greatest precision consistent with the time available should be sought. The hurried use of precise methods may result in mistakes, causing great inaccuracy. A survey which introduces too great an error into the preparation of fire has no value.

In survey work and in the training for it, the following rules should be observed:

a. Use the most precise method possible in the time available.

b. Even though time is pressing, never use a method that is not capable of producing satisfactory firing data.

c. Check all work if only by a rough method. Employ completely independent checks by different men when practicable.

d. Watch particularly the preparation of notes; these must be legible, accurate, and clear. More mistakes occur through badly kept notes than through errors in measurements or calculations.

e. Develop methods and procedures that produce accuracy and eliminate mistakes. Enforce these methods rigidly.

f. Study methods for the weak link. One inaccurate step will destroy the accuracy of an otherwise precise survey.

g. Use selected men. Remove men who do not become precise and methodical with reasonable training. The training in accuracy should parallel that used in training the firing battery.

h. Analyze (and sketch) what the survey is to accomplish, and select the simplest plan which will give the desired results.

Section II. OPERATIONS REQUIRED TO ATTAIN STANDARDS

274. TRAVERSE ACCURACY. Standards of accuracy in traverse and the operations required to attain them are listed below.

a. 1 in 50. An accuracy of 1 in 50 in distance can be obtained by pacing.

b. 1 in 200.

(1) Distance may be obtained by transit stadia, aiming circle stadia, short base, right angle base, or taping. The tape is read to the nearest foot and no slope or other corrections are applied to ground measurements.

(2) Direction is obtained with transit to the nearest 5 minutes or with the aiming circle to the nearest mil (one reading).

(3) Results may be obtained by computing or plotting at a 1/40,000, or larger, scale.

c. 1 in 500.

(1) Distance may be obtained by transit stadia, short base, right angle base, or taping. The tape is read to the nearest 0.1 foot. No corrections

are made for slopes less than 50 feet per 1000 feet; the tape is broken for steeper slopes, and leveled by eye within 5 feet per 100 feet.

(2) Direction is obtained with the transit to the nearest 3 minutes or better, or with the aiming circle to the nearest mil (three cumulative readings).

(3) Results may be obtained by computing or by plotting at a scale not smaller than 1/6667.

d. 1 in 1000.

(1) Distance may be obtained by short base, right angle base, or taping. The tape is read accurately to the nearest 0.1 foot. Slope measurements are made with slope corrections applied. The slope angle is measured with the transit. For horizontal taping, a plumb bob is used on the elevated end of the tape. The tape is leveled by eye within 2 feet for 100-foot sections. The tape is broken as required to obtain level sections.

(2) Direction is obtained with the transit to the nearest minute or better. The aiming circle should not be used.

(3) Results must be obtained by computation. Plotting may be used as a check.

e. 1 in 3000.

(1) Distance may be obtained by triangulation or by direct measurement with a steel tape, read accurately to the nearest 0.1 foot, and estimated to the nearest 0.01 foot. Slope measurements are made with slope corrections applied. The slope angle is measured with a transit or determined from the elevations of the tape points with a hand level and leveling rod, read to the nearest 1/4 foot. For horizontal taping, leveling the tape within 1½ feet by a hand level for each 100-foot section is necessary. The tape is broken as required to obtain horizontal sections.

(2) Direction is obtained with a transit to the nearest 15 seconds, or better. Angles are measured one direct and one reversed, with a 20-second transit. The aiming circle should not be used.

(3) Results must be obtained by computation. Plotting may be used as a check in order to avoid gross errors.

275. SHORT BASE AND RIGHT ANGLE BASE ACCURACY.

a. The accuracy obtained by short base or right angle base is dependent upon the accuracy with which the base length is determined and upon the accuracy with which the angles of the triangle are measured.

b. If the angles measured are correct, the standard of accuracy of the distance determined will be the same as the standard of accuracy used in determining the base length. In other words, if the base length is determined with a standard of 1 in 500, the distance determined

will be accurate to 1 in 500. However, because the angles rarely will be exactly correct, it is necessary to determine the base length with more accuracy than is sought in the distance to be determined, in order to offset partially the errors in the measurement of angles.

c. To obtain the various standards of accuracy, triangles must close (sum of angles = 3200 mils or 180 degrees) as shown below:

For accuracy of 1 in 1000, close within 1 minute.
For accuracy of 1 in 500, close within 1 mil.
For accuracy of 1 in 200, close within 1 mil.

d. If all three angles of the triangle are measured and the triangle does not close within the above limits, all three angles must be remeasured. If all three angles are measured and the triangle closes within the above limits but does not close exactly, the error of closure is divided equally among the three angles.

e. The error which may be expected in a distance determined by short base or right angle base can be estimated by a combination in accordance with the law of errors of the following approximations:

(1) ERROR CAUSED BY MISMEASUREMENT OF BASE LENGTH. Error in determined distance equals standard of accuracy of base length times determined distance.

Example: A base is established with accuracy of 1 in 500. Distance determined is 4500 yards.

Error in determined distance = $1/500 \times 4500$ yards = 9 yards.

(2) ERROR CAUSED BY ERROR IN ANGULAR MEASUREMENTS. For a 1-mil error in the vertex angle, the error in the distance determined =

$$\frac{1}{\text{(vertex angle in mils)}} \times \text{(distance determined)}.$$

Example: A distance is determined by short base as 4500 yards. The vertex angle is 150 mils.

Error in determining distance caused by 1-mil error in vertex angle = $1/150 \times 4500$ yards = 30 yards.

Note. It is obvious that the larger the vertex angle, the smaller will be the resulting error caused by mismeasurement of angles. This should be taken into consideration in the establishment of any base to determine distance.

CHAPTER 8
PROCEDURE

Section I. GRID SHEET

276. GENERAL.

a. The chart which requires the greatest amount of survey work is the grid sheet. The location of all points placed on the grid sheet must be determined either directly or indirectly by survey. The grid sheet is frequently used as the firing chart, supplemented by maps or photos. This procedure might be used when:

(1) The accuracy or scale of the photo or map renders its use as a firing chart unsatisfactory.

(2) The photo or map covers only a portion of the area.

b. If the grid sheet is used as the firing chart in conjunction with a photo or map, pertinent points are transferred to the grid sheet from the photo or map by restitution.

277. DETERMINATION OF BASIC INFORMATION.

a. Since the grid sheet bears no relation to the ground, basic information cannot be obtained from it but must come from other sources. The coordinates and altitude of a point and the azimuth of a line may be obtained in several ways:

(1) The coordinates and altitude of the point may be assumed, and the azimuth of the line measured with an instrument.

(2) The coordinates, altitude, and azimuth may be furnished by a higher echelon. (The battalion never waits for such information from higher echelon but assumes its own as in (1) above, and then converts its survey to conform with the higher control when it becomes available.)

(3) The coordinates, altitude, and azimuth may be taken from a map. This is particularly applicable when small scale maps, inadequate as firing charts are available.

b. The grid sheet may be assigned any scale desired. However, the scale selected is normally one which corresponds to the spacing of the grid lines.

278. BATTALION.

a. General. The survey operations discussed below are for situations where registration is either prohibited or is used for the deter-

mination of corrections only. These operations should always be performed when sufficient time is available. (Rapid methods of establishing a firing chart on a grid sheet by firing are discussed in chapter 3, PART SIX.) Because the grid sheet intrinsically offers no control, the location of all points that are to appear on the chart must be determined by survey from a point of known coordinates and altitude and a line of known azimuth.

b. Target area survey (fig. 125). Normally, if the battalion survey officer assumes his control, he will assume coordinates and altitude for point A and will measure the azimuth from point A to the base point or to some other point in the target area. The control will be extended into the target area by use of the target area base. The target area base is oriented by measuring the instrument reading to the base point, computing the coordinates of the base point, and plotting the base point on the chart (par. 253).

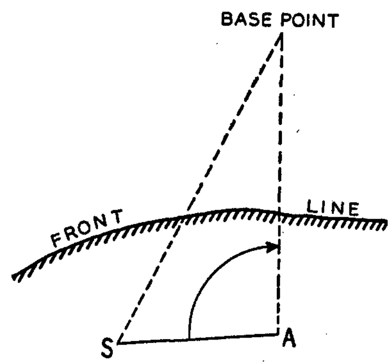


Figure 125. Target area survey when a grid sheet is used.

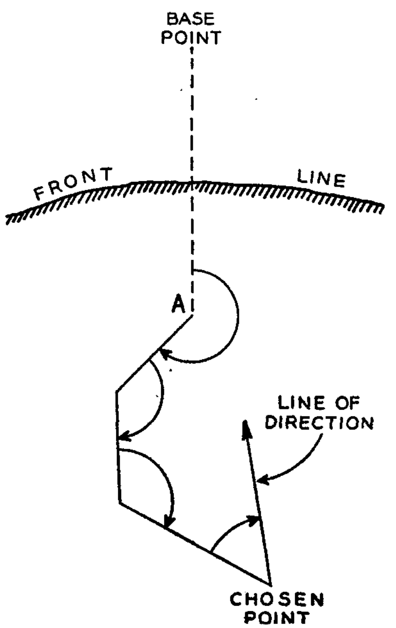


Figure 126. Connection survey when a grid sheet is used.

Vertical locations are established by means of measured vertical angles and surveyed distances. When the basic information is obtained for some point other than point A, the target area survey is still initiated from point A and the results are converted to chart control when the chart data for point A become available. The conversion is performed in the manner discussed in subparagraph d below.

c. Connection survey (fig. 126). Normally, the connection survey is initiated at point A and is based on the known data at that point.

The survey is run (carrying direction, distance, and altitude) to determine the coordinates and altitude of a chosen point, and the azimuth of an arbitrary line of direction from the chosen point in the position area. In case basic information may be obtained in the position area, the connection survey will carry direction, distance, and altitude from the position area to point A.

d. Position area survey (fig. 127).

(1) In order to facilitate the combining of the position area survey with the remainder of the survey, the position area survey is initiated from the chosen point (an arbitrary point used as the origin of the survey); an arbitrary line of direction is used. The survey from the chosen point must carry direction, distance, and altitude to establish the horizontal and vertical locations of the batteries in relation to the

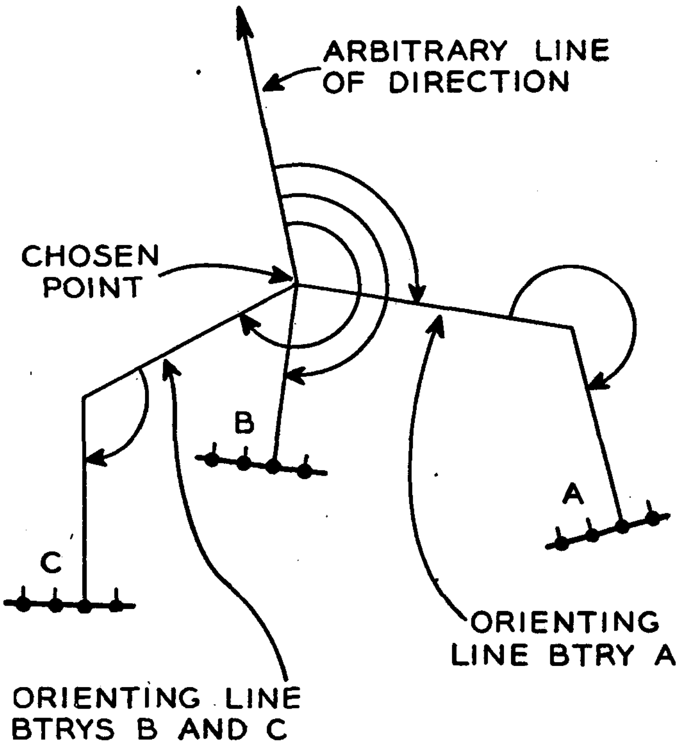


Figure 127. Position area survey when a grid sheet is used.

chosen point, and the relative directions of the orienting lines and the arbitrary line of direction. The chart coordinates and altitude of the chosen point and the chart azimuth of the arbitrary line of direction are determined by the connection survey. If time is limited, the posi-

tion area survey, including the chosen point and the arbitrary line of direction, is plotted (par. 245e) on tracing paper at the grid sheet scale. When the connection survey has determined the chart coordinates of the chosen point and the chart azimuth of the arbitrary line of direction, both are plotted on the grid sheet. The tracing paper is then oriented: the chosen point on the tracing paper is placed over the chosen point on the grid sheet, and the line of direction on the tracing paper over the line of direction on the grid sheet. The battery locations are then pricked through the tracing paper to the grid sheet. If time is ample, instead of plotting the position area survey, the coordinates of the batteries should be computed as soon as the chart coordinates of the chosen point and the chart azimuth of the line of direction are known. The chart altitude of each battery is determined as follows: determine the difference in altitude (obtained by survey) between the battery and the chosen point, and apply this difference to the chart altitude of the chosen point.

(2) The base angles are computed by either the polygon method or the azimuth method.

279. EXAMPLE OF BATTALION SURVEY WHEN A GRID SHEET IS USED (fig. 128).

a. Mission. To deliver massed fires, observed and unobserved, registration prohibited (2 hours available for survey).

b. Situation. The terrain is rolling. There are low hills and scattered woods. Although it is impossible to observe the entire target area, a photo is available showing the area beyond the front lines. Points T and Z are identifiable on both the photo and on the ground. The position area is not visible from either point A or point S. Division control will be available at a later time.

c. Survey operations.

(1) TARGET AREA. The coordinates and altitude of point A are assumed. The *Y*-azimuth of the point A-base point line is measured with the aiming circle. The target area base (AS) is established, and is used to locate the base point, points T and Z, and critical terrain features. Points T and Z will serve as restitution points for transfer of targets from the photo to the grid sheet. Vertical angles to all points located by the base are measured from point A, and their altitudes are computed.

(2) POSITION AREA. The chosen point is selected and marked on the ground. The orienting line for Battery A is staked and is used for the line of direction upon which the position area survey is based. It also serves as the first leg of the traverse to Battery A. The orienting

line for Batteries B and C is staked in, and traverses are run to the batteries. The chosen point, the three batteries, and the orienting line of Battery A are plotted on a piece of tracing paper.

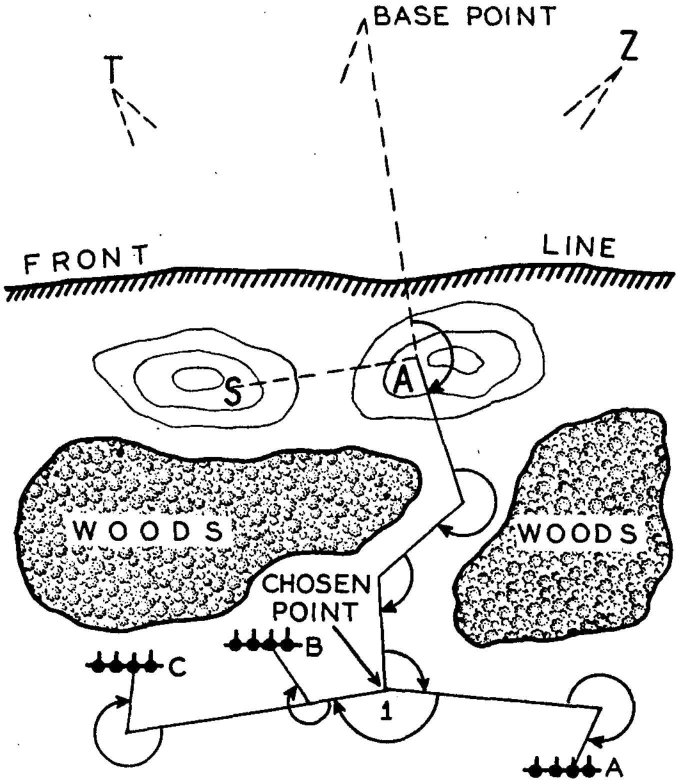


Figure 128. Battalion survey when a grid sheet is used.

(3) CONNECTION. Initial direction is taken from the line, point A-base point. The coordinates and altitude of the chosen point and the azimuth of the orienting line of Battery A are determined by survey.

(4) GENERAL. After the coordinates of point A, the base point, the restitution points, and the chosen point have been determined, they are plotted on duplicate charts. A line of the same azimuth as the orienting line of Battery A is drawn through the chosen point. The tracing paper is oriented and the batteries are pricked through. The base lines of all batteries are drawn on the chart, and their azimuths measured. The azimuth of the Battery A orienting line is known. The azimuth of the orienting line of Batteries B and C is computed, using angle 1. The base angles are computed by the azimuth method and are written on the chart.

280. HIGHER ECHELONS.

a. General. When the grid sheet is the basis of the firing chart, each subordinate unit that is to be placed on common control must be furnished the coordinates and altitude of a point which is identified on the ground, and a line of direction from that point. The direction may be furnished as:

(1) An azimuth from the point, the coordinates of which are furnished, to another point visible from the first.

(2) The coordinates of two intervisible points, one of which can be occupied and used as a basis for survey.

b. Corps. When the artillery with the corps is to be placed on common control, the minimum control that will be furnished by the corps observation battalion is the coordinates and altitude of a point and a line of direction, in the area of each division, brigade, or separate battalion of the corps. This control will normally be established in the vicinity of the gun positions. The observation battalion frequently will be able to establish control in the observation area (area affording observation of the target area) since it must extend control to the observation area for its flash installations. Often this observation area control can save battalions time and effort by eliminating connection surveys between the position areas and the observation area.

c. Division artillery. The division artillery survey section will furnish each battalion of the division the coordinates and altitude of a point in the battalion area, and a line of direction from the point. In addition, the coordinates and altitude of a division artillery check point in the target area may be furnished, and the check point identified on the ground. Since the locations of battalion position areas are usually known to the division artillery survey officer before he knows the locations of battalion observation posts, normally the point and line of direction will be furnished in the vicinity of the position areas. If photomaps are available, division artillery must also furnish the photomap coordinates and the grid sheet coordinates of at least two points to be used for restitution.

281. EXAMPLE OF DIVISION ARTILLERY SURVEY WHEN A GRID SHEET IS USED (fig. 129).

a. Mission. To extend common control (furnished by corps) to all battalions of the division. Five hours available for survey.

b. Situation. The terrain is rolling and slightly wooded. The corps observation battalion has furnished the coordinates of points A and B and the altitude of point A.

c. Survey operations. Points A and B are identified to the survey officer of the 4th Battalion and he is given the necessary coordinates and altitude. The division survey is initiated at point A, taking direction from the AB line. Point M is located, and its coordinates and altitude and the coordinates of point A are given to the survey officer of the 3d Battalion, and both points are identified to him. Point N is located and the azimuth of the NO line is measured. Points N and

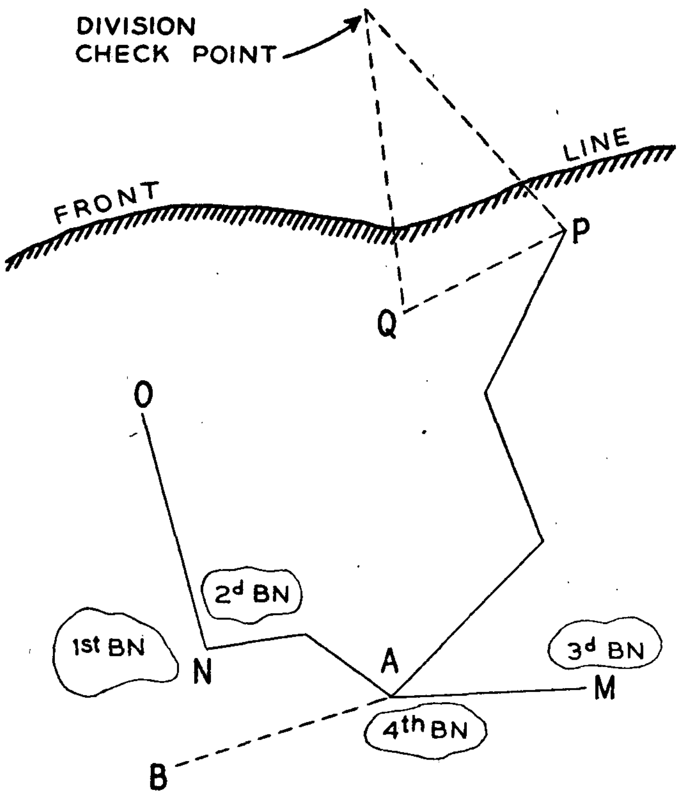
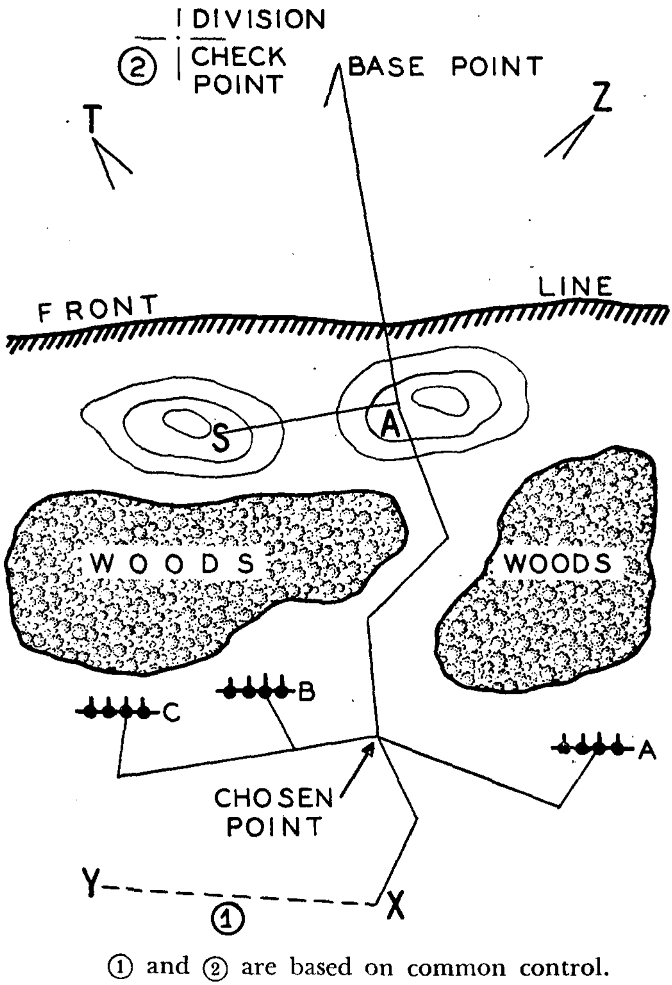


Figure 129. Division artillery survey when a grid sheet is used.

O are identified to the survey officers of the 1st and 2d Battalions and the coordinates and altitude of point N and the azimuth of the line NO are given to them. When control has been extended to all battalions, it is carried forward and the base PQ is established. From this base the coordinates and altitude of the division check point are determined. The coordinates and altitude of the check point are given to all battalions and the check point is identified to them on the ground.

282. TRANSFERRING FROM ASSUMED CONTROL TO COMMON CONTROL (fig. 130). (This is a continuation of the example in par. 281.)



① and ② are based on common control.

Solid lines indicate assumed control.

Figure 130. Converting from assumed to common control.

a. Mission. To transfer the battalion chart, which is based on assumed control, to common control.

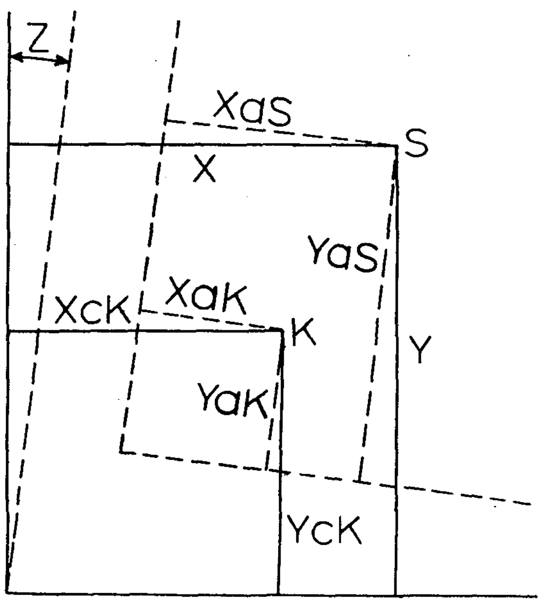
b. Situation. The battalion survey is complete and the battalion has been firing from a chart which is based on control assumed by the battalion survey officer. The division artillery survey officer has iden-

tified points X and Y on the ground and has given their coordinates and the altitude of point X to the battalion survey officer.

c. Survey operations. A survey is initiated using the battalion chosen point as point of origin, and the coordinates and altitude of point X and the coordinates of point Y are determined by traverse based on the battalion assumed control.

d. Transferring.

(1) BY PLOTTING. Points X and Y (their coordinates based on assumed control) are plotted on the battalion chart. An overlay is made of all points on the battalion chart that are to be transferred and of points X and Y. On a new grid sheet, points X and Y are plotted at their common control coordinates. The overlay is oriented upon the new grid sheet: point X of the overlay is placed over point X of the grid sheet and line XY on the overlay is brought into coincidence with XY on the grid sheet. All points on the overlay are pricked through and the resulting chart is on common control. The difference in the



Solid lines indicate common control.

Dotted lines indicate assumed control.

Figure 131. Conversion of grid coordinates.

altitude of point X based on assumed control and point X based on common control is determined. This difference is applied to all alti-

tudes based on assumed control in order to obtain their common control altitudes. This is the most rapid method of transferring from one type control to another and is usually sufficiently accurate for light and medium artillery.

(2) BY COMPUTING.

(*a*) A more accurate method of transferring from assumed to common control is by computation. This is the method normally used by heavy artillery and higher survey echelons. In the computation method, the common control coordinates of critical points, such as all batteries, point A, base point, check points, and restitution points, are computed and plotted. When all critical points have been plotted at their common control coordinates, other points, such as targets, may be transferred to the new chart by instrument readings and distances from point A, or by deflection shifts and ranges from the batteries measured on the old chart. Altitudes are determined as in the plotting method.

(*b*) In computing the common control coordinates of the critical points, the following formulas are used (fig. 131):

$$X = XcK + ((XaS - XaK) \cos Z + (YaS - YaK) \sin Z).$$

$$Y = YcK + ((YaS - YaK) \cos Z - (XaS - YaK) \sin Z).$$

In the formulas above, if Z is positive, cos Z and sin Z are positive; if Z is negative, cos Z is positive and sin Z is negative. If the angle Z is greater than 1600 mils, the true trigonometric sign of the function must also be applied. These formulas are the basis of the tabular method of conversion illustrated in figures 132 and 133. The following examples illustrate conversion of coordinates by the tabular method.

(*c*) Example (fig. 132): Assume in the situation in (*b*) above that the following data have been determined based on assumed battalion control:

Coordinates	X =	20.420–36.950
	A =	4640 mils.
Azimuth	XY =	19.380–40.320

Common control has been furnished as follows:

Coordinates	X =	40.220–63.580
Azimuth	XY =	4760 mils.

The common control coordinates of point A are desired.

Common-control azimuth	4760		
Assumed-control azimuth	-4640	Log cos Z =	9.99698
Z =	+ 120	Log sin Z =	9.07018
Assumed coord of sought pt	19.380		40.320
Assumed coord of known pt	-20.420		-36.950
dx	- 1.040	dy	+ 3.370
Log dx	0.01703	Log dy	0.52763

Log dx	0.01703		Log dy	0.52763	
Log cos Z	+9.99698		Log cos Z	+9.99698	
Antilog	0.01401	-1.033	Antilog	0.52461	+3.347
Log dy	0.52763		Log dx	0.01703	
Log sin Z	+9.07018		Log sin Z	+9.07018	
Antilog	9.59781	(+)+.396	Antilog	9.08721	(-) -0.122
		-.637			+3.469
X coord, known pt, common control		+40.220	Y coord, known pt, common control		+63.580
X coord, sought pt, common control		39.583	Y coord, sought pt, common control		67.049

NOTES: a. Known point = point whose assumed and common grid coordinates are known.

b. Sought point = point whose assumed coordinates are known and whose common grid coordinates are sought.

c. If Z is negative, sin Z is negative, but cos Z remains positive.

d. If angle Z is greater than 1600 mils the true trigonometric sign of the function must be applied in addition to c above.

Figure 132. Example of conversion of assumed to common grid coordinates by use of tabular method.

(*d*) Example (fig. 133): Assume in the situation in (*c*) above that the following data have been determined based on assumed battalion control:

Coordinates X = 19.470—20.310
A = 20.890—16.420
Azimuth XY = 1570 mils.

Common control has been furnished as follows:

Coordinates X = 39.820—71.210
Azimuth XY = 1490 mils.

The common control coordinates of point A are desired.

Common-control azimuth	1490		
Assumed-control azimuth	−1570	Log cos Z =	9.99866
Z =	− 80	Log sin Z =	8.89464
Assumed coord of sought pt	20.890		16.420
Assumed coord of known pt	−19.470		−20.310
dx	+ 1.420	dy	− 3.890
Log dx	0.15229	Log dy	0.58995

Log dx	0.15229		Log dy	0.58995	
Log cos Z	+9.99866		Log cos Z	+9.99866	
Antilog	0.15095	+ 1.416	Antilog	0.58861	−3.878
Log dy	0.58995		Log dx	0.15229	
Log sin Z	+8.89464		Log sin Z	+8.89464	
Antilog	9.48459	(+) +.305	Antilog	9.04693	(−) −.111
		+1.721			−3.767
X coord, known pt, common control		+39.820	Y coord, known pt, common control		+71.210
X coord, sought pt, common control		41.541	Y coord, sought pt, common control		67.443

NOTES: a. Known point = point whose assumed and common grid coordinates are known.

b. Sought point = point whose assumed coordinates are known and whose common grid coordinates are sought.

c. If Z is negative, sin Z is negative, but cos Z remains positive.

d. If angle Z is greater than 1600 mils the true trigonometric sign of the function must be applied in addition to c above.

Figure 133. Example of conversion of assumed to common grid coordinates by use of tabular method.

e. Use of the division check point. The division check point is used for determination of corrections by registration to insure massing of the division in the critical sector of the division.

Section II. BATTLE MAP

283. GENERAL.

a. A battle map is a map based on ground control with detail supplied by photogrammetric means, the whole produced at such a scale as to make it suitable for use as a firing chart. A battle map is as accurate as the ground survey from which the map is made. The survey on which the map is based normally is indicated in the lower margin of the map. When one map of a series, made from the same ground survey, proves to be accurate, the implication is that the remainder of the series is accurate. In like manner, if one map of a series proves to be inaccurate, the remainder of the series should be regarded with suspicion. Some maps are made entirely from aerial photographs with no ground survey at all, and will have an accuracy no better than that of an uncontrolled mosaic. Normally, a warning as to this inaccuracy will be printed on the map. When a battle map is based on accurate ground survey, any point or any line on the map, with the exception of paths and trails, will be located with sufficient accuracy to be used as the basis for field artillery survey. If the map is not based on accurate and adequate ground control, it should be used only to supplement a grid sheet firing chart by restituting points (par. 199) from the map to the grid sheet. Restitution does not remove the errors. It merely ties individual points to a correct framework of critical points.

b. The survey procedure discussed in the remainder of this section is applicable only to battle maps based on accurate and adequate ground control.

The chart requiring the least amount of survey work is the battle map, which affords horizontal and vertical control and direction throughout the area covered by the map. The most unfavorable characteristic of the battle map is the fact that roads or other objects shown on the map may have changed position on the ground since the map was made. For this reason it is desirable to use a more or less permanent object (triangulation marker, concrete road, railroad, permanent bridge, grid control point, etc.) for obtaining control upon which to base a survey.

284. DETERMINATION OF BASIC INFORMATION. Basic information is obtained from the battle map as follows:

a. Coordinates or map location of some ground points may be determined by inspection. Resection is particularly applicable for locat-

ing a point on the battle map if three other visible points can be located on the map by inspection.

b. The altitude of a ground point may be determined from the contour lines or for certain prominent points from spot altitudes printed beside them on the map. Spot altitudes are more accurate than contour altitudes.

c. The *Y*-azimuth of a line on the ground may be determined by:

(1) MEASURING FROM A MAP. If two points marking a line on the ground can be located on the map, or if a straight road, railroad, fence, etc. is identifiable on the map and on the ground, the azimuth of the line can be measured from the map with a protractor. It is always desirable (in higher echelons and heavy artillery, it is essential) that a line used to establish direction be not less than 1000 yards in length.

(2) ASTRONOMIC METHODS. The true azimuth of the line on the ground is determined by astronomic methods. The true azimuth is then converted to *Y*-azimuth by the application of the difference in true and *Y*-azimuth indicated in the margin of the map.

d. The scale of the battle map is indicated in the margin.

285. BATTALION SURVEY; 4 HOURS OR MORE AVAILABLE.

a. General. This method is used when ample time is available for survey. However, unless it is definitely known that the firing chart will not be needed before this type of survey can be completed, the chart is established as in paragraph 287 and later checked by this method.

b. Target area survey. Point A is located by inspection, if possible. If it cannot be located by inspection, it is located by survey from a point where the necessary basic information can be obtained from the map. The altitude of a point A is determined from contour lines or spot altitudes and this control is extended into the target area by vertical angles. The target area base is oriented as follows:

(1) Preferably by an instrument reading to a point in the target area that is identifiable on the map.

(2) If no point in the target area is identifiable on the map, by an instrument reading to a point in the target area that is plotted on the map by computed coordinates. The computed coordinates of the point are based on the coordinates of point A and on the *Y*-azimuth of a line from point A to an identifiable point in the battalion area. The distance used in computing the coordinates of the point is determined by the target area base.

c. Connection survey. The connection survey is initiated at point A and carries *Y*-azimuth only to the position area. It is based on the

Y-azimuth of the line from point A to the point in the target area used to orient the target area base.

d. Position area survey. The position area survey is initiated from a point, the location of which can be obtained by resection or by inspection from the map. Altitudes of batteries are determined from the contours or by survey from the altitude of this point. An arbitrary line of direction from this point is selected. This point and the arbitrary line of direction are used in the same way as the chosen point and line of direction are used in survey for a grid sheet firing chart (par. 278d). The *Y*-azimuth of the arbitrary line of direction is determined by the connection survey, and the chart locations of the batteries are determined using this *Y*-azimuth and the map coordinates of the point from which the position area survey was initiated. The batteries are plotted on the chart, and the base angles computed by either the polygon or azimuth method.

e. Use of astronomic methods. The connection survey can be eliminated and the same results obtained by establishing relative directions in the target area and position area by astronomic methods.

286. EXAMPLE: BATTALION SURVEY; 4 HOURS AVAILABLE (fig. 134).

a. Mission. To deliver massed fires, observed and unobserved, registration prohibited.

b. Situation. Terrain is rough and heavily wooded. Numerous points in the battalion area are identifiable on the map. A building, B, in the target area is identifiable on the map.

c. Survey operations.

(1) TARGET AREA. The horizontal and vertical location of point A is determined by traverse from M. The target area base is established and is oriented by use of B.

(2) CONNECTION. The connection survey carries *Y*-azimuth from the line AB to the arbitrary line of direction QN used by the position area survey.

(3) POSITION AREA. The road QN is used as an arbitrary line of direction; the position area survey is initiated from Q; a traverse, carrying distance, direction, and altitude, is run to all batteries. The direction of the orienting line is determined with regard to QN. When the *Y*-azimuth of QN is determined by the connection survey, the coordinates of the batteries are computed and plotted, and the base angles are computed.

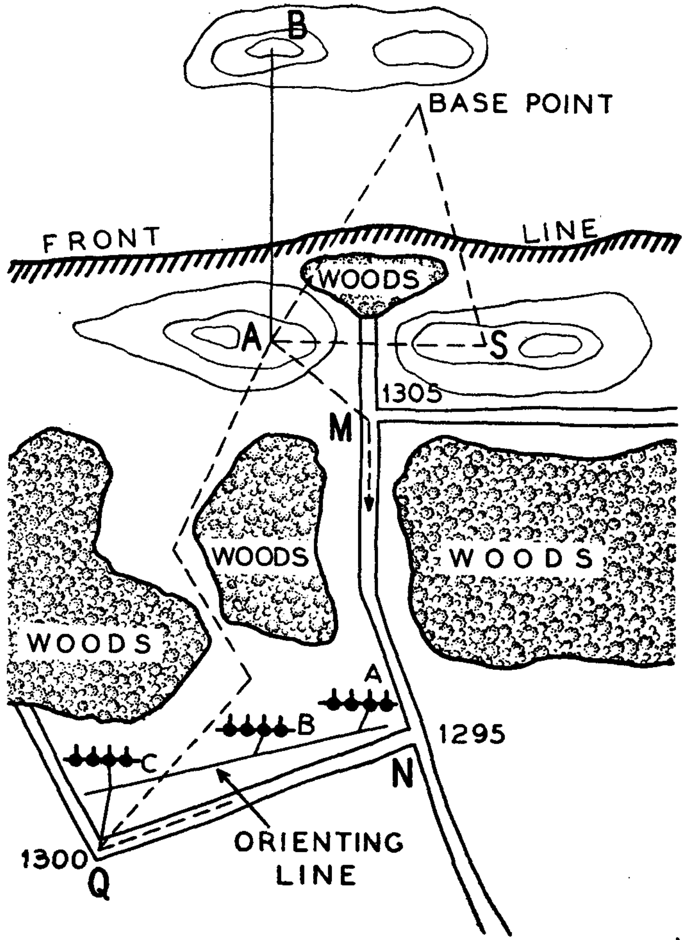


Figure 134. Battalion survey when a battle map is used; 4 hours or more available for survey.

287. BATTALION SURVEY; 2 TO 4 HOURS AVAILABLE.

a. General. If time does not permit a complete survey (par. 285), the chart is constructed based on the operations below. This survey is checked by a complete survey when initial charts are completed.

b. Target area survey. The target area survey operations are identical with those of the more deliberate survey (par. 285).

c. Connection survey. No connection survey is run because of shortage of time.

d. Position area survey. Batteries are located by inspection or by resection and traverse from identifiable points. Altitudes of batteries

are taken from contour lines. *Y*-azimuths of orienting lines are determined by survey from a line whose *Y*-azimuth is measured on the map. Base angles are computed by the azimuth method, with *Y*-azimuths of the base lines measured on the map.

288. EXAMPLE: BATTALION SURVEY; 2 HOURS AVAILABLE (fig. 135).

a. Mission. To deliver massed fires, observed and unobserved, registration prohibited.

b. Situation. Terrain is rough and heavily wooded. Numerous points in the battalion area are identifiable on both the ground and on the map. A building, B, is identifiable in the target area.

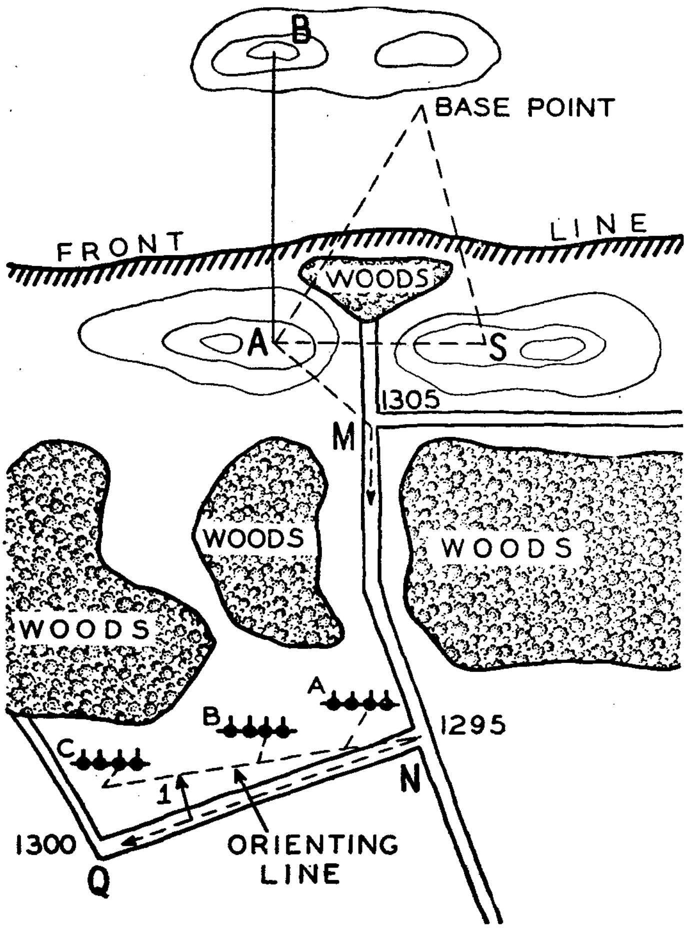


Figure 135. Battalion survey when a battle map is used; 2 hours available for survey.

c. Survey operations.

(1) TARGET AREA. The coordinates and altitude of point A are determined by traverse from M. Target area base (AS) oriented by point B.

(2) CONNECTION. From map.

(3) POSITION AREA. The coordinates and altitudes of the batteries are determined by traverse from N. *Y*-azimuth of the orienting line is determined by application of angle 1 (measured on the ground) to the *Y*-azimuth of the road NQ (measured from chart, because of lack of time). Batteries are plotted on map, base lines drawn, and *Y*-azimuths of base lines measured from the chart. Base angles are computed by the azimuth method.

289. BATTALION SURVEY; 1 TO 2 HOURS AVAILABLE.

a. General. The procedure outlined below is for situations where time is very limited and registration is permitted. Accuracy is sacrificed for speed. As soon as a chart is completed, the survey procedure outlined above is started to produce a more accurate chart.

b. Target area survey. All points in the target area are located by inspection if possible. The target area survey is the same as for the more deliberate survey (par. 285) except that to a certain extent accuracy is subordinated to speed. If traverse is necessary to locate point A, short distances are paced and longer distances are taped on the run. All altitudes are taken from contour lines.

c. Connection survey. No survey is run. The connection survey is accomplished by registration.

d. Position area survey. Batteries are located by inspection or by traverse. Short distances are paced, longer distances taped on the run. Orienting lines are staked in. No attempt is made to determine the *Y*-azimuth of the orienting lines; but, if more than one orienting line is used, the relative directions of all orienting lines must be established by directional traverse. Batteries are plotted on the map and the base lines are drawn. When the registering battery's base angle, determined by adjustment, is reported, the nonregistering batteries' base angles are computed by applying to the base angle of the registering battery the base point offsets (measured from the map) and any variation in the direction of the orienting lines.

290. EXAMPLE: BATTALION SURVEY; 1 HOUR AVAILABLE (fig. 136).

a. Mission. To mass the fires of the battalion, registration permitted.

b. Situation. Terrain is rough and heavily wooded. Numerous points in the battalion area are identifiable on the map. A building, B, is identifiable in the target area and on the map.

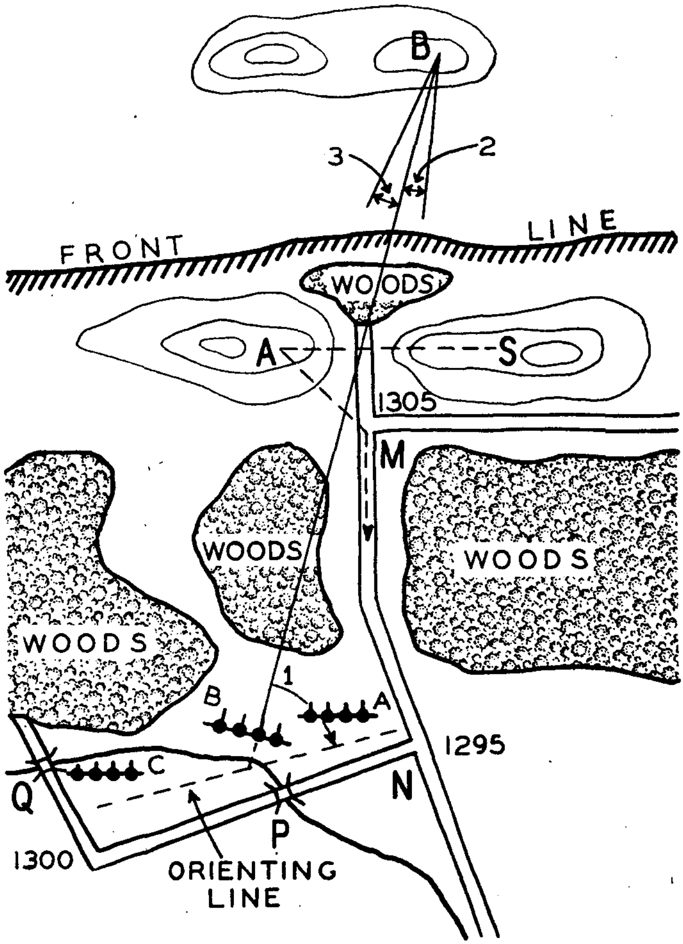


Figure 136. Battalion survey when a battle map is used; 1 hour available for survey.

c. Survey operations.

(1) TARGET AREA. Point B is located by inspection on the map and assigned as the base point. The altitude of point B is determined from the contours. Point A is located by traverse from M. Altitude of A is taken from contours. The AB line is used to orient the target area base.

(2) CONNECTION. None performed.

(3) POSITION AREA. The batteries are located by inspection from points N, Q, and P. The orienting line is staked in on the ground; no effort is made to establish its direction. Base lines are drawn on the chart. Battery B registers and reports its base angle (angle 1). Base angles for Batteries A and C are computed by applying offsets (angles 2 and 3) measured from the chart to the base angle of Battery B.

291. OPERATIONS OF HIGHER ECHELONS.

a. General. If the battle map is accurate and all units exercise care in obtaining basic information from the map, all units initiating their survey on basic information taken from the map will be on common control.

b. Corps. The corps observation battalion supplements control furnished by the map when ground points identifiable on the map are not sufficient to fulfill the needs of the corps. The observation battalion also checks the accuracy of location of points on the map.

c. Division artillery. The division artillery survey section initiates its survey on basic information obtained from the map or on control furnished by the corps observation battalion if such control is available. The control is extended to each battalion area. If the battalion has initiated survey based on basic information obtained from the map, the division artillery checks the accuracy of such basic information. Division artillery also furnishes the coordinates, altitude, and ground location of the division check point.

Section III. PHOTOMAP

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292. CHARACTERISTICS OF THE PHOTOMAP.

a. Favorable.

(1) The photomap provides a wealth of up-to-date detail; points can be located in both the position area and target area with a minimum of survey, thereby greatly facilitating horizontal control.

(2) Because it looks like the ground, the photomap provides the best medium for designation of targets by supported arms.

b. Unfavorable.

(1) Because of errors in photos caused by tilt and by distortion due to relief, and because of errors in mosaics due to poor assembly, all photomaps must be regarded with suspicion until their accuracy has been checked.

(2) If points cannot be located on the photo by inspection, the photo scale must be determined before the points can be located on the photo by survey.

(3) Vertical control can be determined on a photomap only by estimation.

293. USE OF THE PHOTOMAP AS A FIRING CHART.

a. For unobserved fires, additional coverage (see chap. 1, PART SIX) is sought and ammunition expended until the accuracy of the photomap, having been checked by survey or firing, indicates that extra coverage and ammunition expenditures are unnecessary.

b. Even though the photomap is used initially, a grid sheet survey is started at once. This survey provides a check on the accuracy of the photomap, and, if the photomap proves to be inaccurate, provides an accurate firing chart.

(1) If the photomap is found to be in error, targets can be restituted from the photomap to the grid sheet. Since the methods of restitution do not eliminate errors in the photomap (par. 199), unobserved fires on restituted targets will require larger coverage and ammunition expenditure. However, by determining restituted grid coordinates, the fires of more than one battalion can be massed at a point.

(2) If the survey for a grid sheet proves the photomap to be accurate in the entire division zone or sector, the photomap continues to be the chart for maneuver of fires with normal coverage and ammunition.

(3) Although the photomap is sufficiently accurate in most cases for a battalion firing chart, the grid sheet or battle map is usually necessary for massing or maneuvering the fires of the division artillery and those of the corps.

c. When the photomap is used as the firing chart, the survey procedure is basically the same whether the photomap is a controlled mosaic, an uncontrolled mosaic, or an individual vertical, although points can and should be corrected for relief distortion on the individual vertical. Points usually cannot be corrected for relief distortion on a mosaic because photo centers cannot be determined.

294. CHECKING THE ACCURACY OF THE PHOTOMAP. The assembly of different photos into a photomap results in errors of distance and direction in the photomap. These errors are best ascertained by determining the surveyed locations of numerous points (in both the target and position areas) which are identifiable on the photomap. The surveyed points are then plotted by coordinates on a grid sheet. To determine the accuracy of the photomap for distance, measure the distances between points in the position area and target area on the

grid sheet; scale the distances between the same points on the photo map and convert to ground distances by use of the photo-ground relationship; compare the respective distances. If the variations in the respective distances exceed 100 yards, the photomap must be considered unsatisfatory as a firing chart. To determine the accuracy of the photomap for direction, measure from points in the position area (vertex at points in the position area) the angles between points in target area on both the grid sheet and photomap; compare the respective angles measured on each chart and convert the angular error to yards through use of mil relation. If the variation exceeds 50 yards, the photomap is not sufficiently accuratè for use as a firing chart.

If time does not permit a survey for a grid sheet, the accuracy of the photomap may be checked by firing by comparing the observer's sensings of effect with the standards set forth above.

295. DETERMINATION OF BASIC INFORMATION. Basic information is obtained from the photomap as follows:

a. *Photomap locations of ground points may be determined by in spection.*

b. Altitude of a point may be assumed or may be furnished by high er echelon.

c. *Y*-azimuths cannot be measured from photomaps because when the photomaps are made no effort is made to orient the grid lines in relation to *Y*-north (par. 189). The grid lines can be used, however, to determine relative azimuths of ground lines which appear on the photomap. To accomplish this, the grid lines are given an assumed azimuth. The relative azimuth of any desired line can then be determined by measuring the angle of intersection made by the line whose azimuth is desired and a grid line, and applying this angle to the azimuth of the grid line. The azimuth given to the grid lines can be determined by:

(1) Assumption, if it is not necessary to orient the photomap.

(2) Determining the azimuth of a ground line by measuring it with an instrument or by using astronomic methods, measuring the angle of intersection of this line and a grid line on the chart, and computing the azimuth of the grid using the ground azimuth and the chart angle of intersection.

The relative azimuths determined will include errors caused by erroneous photo locations of the points marking the ends of the lines, and should be checked by survey when time permits.

d. The scale of the photomap is determined as outlined in paragraph 195.

296. BATTALION SURVEY; 4 HOURS OR MORE AVAILABLE.

a. General. The following method of survey is used when ample time is available for survey. However, unless it is definitely known that the chart will not be needed before this type of survey can be completed, the chart is established as in paragraph 298, and later checked by this method. Normally, if 4 hours were available for survey, a grid sheet survey would be run unless the photomap was known to be accurate.

b. Target area survey. Point A is located by inspection if possible. (If it cannot be located by inspection, it is located by survey from a point where the necessary basic information can be determined.) If no data are furnished by higher echelon, the battalion survey officer will establish azimuth and altitude for the photomap at point A. The length of the target area base is always expressed in photo units so that ranges determined will be in photo units and may therefore be plotted on the photomap without conversion.

(1) The length of the base can be determined in one of two ways.

(*a*) If possible, locate a point in the target area which is identifiable on the photomap. Measure the angles to the point from each end of the base. Measure from the photomap the distance in photo units from point A to the point in the target area. Compute the photo length of the base as outlined in paragraph 241. Determine the scale of the photomap, using the same point in the target area, by comparing the photomap distance and the ground distance to the point from point A. The ground distance is computed by determining the ground length of the base.

(*b*) If no point in the target area is identifiable on the photomap, determine the ground length of the base by survey and convert it to photo length by use of the photo-ground relationship. The photo-ground relationship in this case must be determined by using points in the position area which are identifiable on the photomap.

(2) The target area base is oriented as follows:

(*a*) Preferably by an instrument reading to a point in the target area that is identifiable on the photomap.

(*b*) If no point in the target area is identifiable, use an instrument reading to a point in the position area which is identifiable on the photomap.

c. Connection survey. The connection survey is initiated at point A, and carries azimuth and altitude to the position area. It is based on the azimuth of the line used to orient the target area base. The distances used in computing altitudes are obtained by locating stations on the photomap by inspection, measuring the distances between sta-

tions from the photo, and converting the measured photo distances to ground distances.

d. Position area survey. The position area survey is initiated from a chosen point, the location of which can be obtained by inspection from the photomap, and is based on an arbitrary line of direction from this chosen point. The horizontal locations of the batteries with respect to the chosen point, and the difference in altitudes between the batteries and the chosen point are determined. The ground distances determined by survey are converted to photo distances, and the position area survey is plotted on tracing paper. The connection survey furnishes the photo azimuth of the arbitrary line of direction, and the batteries are plotted as in paragraph 278d. The connection survey also furnishes the chosen point altitude from which the altitudes of the batteries are determined.

e. Use of astronomic methods. The connection survey can be eliminated and the same results obtained by establishing relative directions in the target area and in the position area by astronomic methods. If no connection survey is run, relative altitudes are established as described in paragraph 298d.

f. Accuracy check. As soon as the firing chart is complete, the survey operations which have been performed are supplemented, as necessary, to provide sufficient data for grid sheet locations of points in the position area and in the target area. Photomap ranges and angles are compared with corresponding grid sheet ranges and angles to determine whether the photomap is a suitable firing chart.

297. EXAMPLE: BATTALION SURVEY; 4 HOURS AVAILABLE (fig. 137).

a. Mission. To deliver massed fires, observed and unobserved, registration prohibited.

b. Situation. Terrain is rolling. There are scattered woods. Numerous points in the battalion area and in the target area are identifiable on the photomap.

c. Survey operations.

(1) TARGET AREA. Point A is located by inspection (by its proximity to the intersection of two paths). Point B in the target area is located by inspection. The azimuth of AB is measured with an instrument and its azimuth imparted to the grid.

The length of the target area base is computed from the distance AB measured on the chart. The base is oriented by an instrument reading to point B. The altitude of point A is assumed; altitudes of points in the target area are determined by vertical angles from point

A. The scale of the photo is determined by comparison of the photo length with the ground length of AB. (The ground length of AB is obtained by determining the ground length of the base AS.)

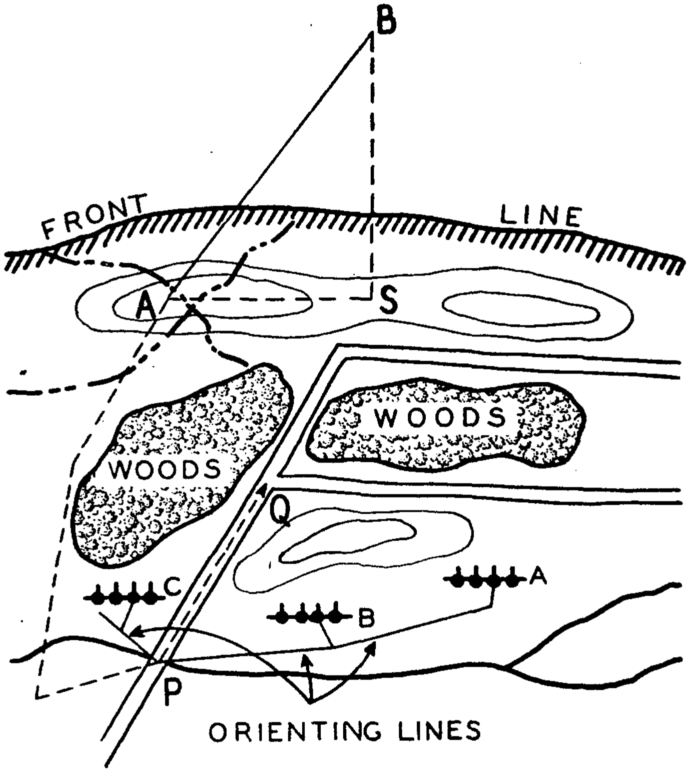


Figure 137. Battalion survey when a photomap is used; 4 hours available for survey.

(2) CONNECTION. The connection survey is initiated at point A and is based on the measured azimuth of the line AB. Azimuth is carried to the position area, and the azimuth of PQ is determined. Altitude of point P is determined by vertical angles measured on the ground and by distances obtained by applying the photo-ground relationship to distances measured from the photomap between stations located approximately by inspection.

(3) POSITION AREA. The position area survey is initiated at P and based on PQ. A complete traverse is run to locate all batteries and to establish orienting lines. Using the photo-ground relationship determined by target area survey, the position area survey ground distances are converted to photo distances and are plotted on tracing

paper. As soon as the connection survey has determined its azimuth, the line PQ is plotted; the position area overlay is oriented; and the batteries are pricked through. The altitudes of the batteries are computed based on the altitude of P as determined by the connection survey. The base lines are drawn, and base angles are computed by either the polygon or the azimuth method. If the azimuth method is used the azimuths of the base lines are measured from the photomap.

298. BATTALION SURVEY; 2 TO 4 HOURS AVAILABLE.

a. General. If time does not permit a complete survey (par. 296), the chart is constructed by operations set forth below.

b. Target area survey. The target area survey operations are identical with those of more deliberate survey (par. 296).

c. Connection survey. No connection survey is run.

d. Position area survey. Batteries are located by inspection or by traverse from identifiable points. Photomap azimuths of the orienting lines are determined by survey from a ground line, the photomap azimuth of which is measured from the chart. Base lines are drawn and their azimuths measured from the photomap. Base angles are computed by the azimuth method. Since no connection survey is run, provision must be made for determining the altitude of the batteries with relation to point A. This is done by one of the following:

(1) By *altimeters.*

(2) By use of a *reference point* visible from both point A and the position area, and identifiable on the photomap. If this method is used, the vertical angle is read from point A to the reference point, and the altitude of the reference point is computed using the converted distance scaled from the photomap. The altitudes of the batteries are determined by vertical angles from the batteries to the reference point and by converted distances measured from the photomap.

(3) By an *air burst,* if registration is permitted. The method is as follows: one battery registers on the base point and determines the time setting for a zero height of burst at the base point. At each battery and at point A, an observer orients an instrument, preferably a battery commander's telescope, in the general direction of the base point. After alerting all observers, the registering battery, using the time setting determined for the base point, fires an air burst using a site large enough to make the burst visible from all positions. This round is used to insure orientation of the observers. Another round is fired with the samé data, and an arbitrary altitude is assigned its point of burst. All observers measure the angle of site to the burst. By the mil

relation (using the vertical angles determined by the observers, and the converted photomap ranges from point A and the batteries to the base point) the altitudes of the batteries and of point A are computed.

(4) If none of the methods described above is possible, and time prevents a connection survey, the photo is streamlined, and altitudes are determined by estimation.

299. EXAMPLE: BATTALION SURVEY; 2 HOURS AVAILABLE (fig. 138).

a. Mission. To deliver massed fires, observed and unobserved, registration prohibited.

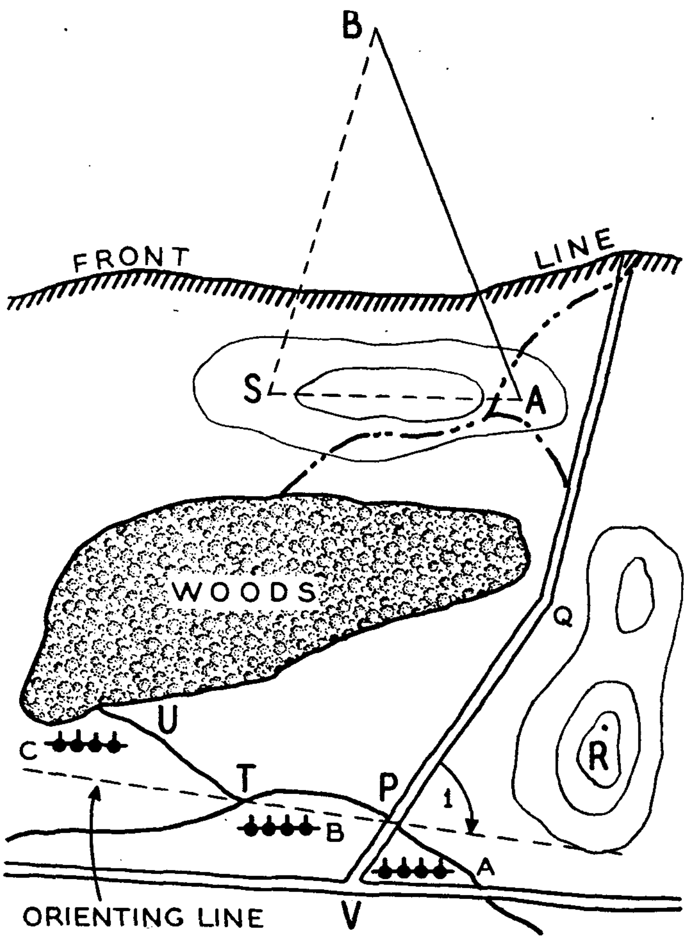


Figure 138. Battalion survey when a photomap is used; 2 hours available for survey.

b. Situation. Terrain is rough. There are scattered woods. Numerous points in the battalion area and in the target area are identifiable on the photomap. Point R is visible from points A and P.

c. Survey operations.

(1) TARGET AREA. Points A and B are located by inspection. The azimuth of the line AB is measured with an instrument and its azimuth imparted to the grid. The length of the target area base is determined in photo units by use of the distance AB, measured from the photomap. The ground length of the base is determined by taping. The ground length of AB is computed, and the scale of the photomap determined by comparing the photomap and the ground length of AB. The altitude of point A is assumed. Altitudes in the target area are determined by vertical angles from point A. The vertical angle from point A to point R is measured, and the altitude of point R is computed, using the converted distance AR measured from the photomap.

(2) CONNECTION. No connection survey is run.

(3) POSITION AREA. Batteries are located by inspection from points T, U, V, and P. The orienting line is established on the ground, and its azimuth is determined by applying angle 1 (measured on the ground) to the azimuth of PQ measured from the photomap. The base lines are drawn in, and their azimuths measured from photomap. Base angles are computed by the azimuth method. The vertical angle from point P to point R is measured. From the altitude of R, using the converted distance from P to R determined from the photomap, the altitude of point P is computed. Based on the altitude of point P, the altitudes of the batteries are computed.

300. BATTALION SURVEY; 1 TO 2 HOURS AVAILABLE.

a. General. The procedure outlined below applies when time is very limited and registration is permitted. Accuracy is sacrificed for speed.

b. Target area survey. A point in the target area which is identifiable on the photomap is selected as the base point. All points in the target area are located by inspection if possible. Points in the target area which cannot be located by inspection are located in the same manner as in the more deliberate survey (par. 296) except that less accuracy is sought. The length of the target area base is determined by use of the distance from point A to the point of known location in the target area (par. 296). If traverse is necessary to locate point A, short distances are paced and longer distances are taped on the run. An approximate photomap scale is obtained by comparing the ground and photomap distances between two convenient points. This scale

does not need to be particularly accurate since it is used only to convert photo distances to ground distances for purposes of computing altitudes. The setting on the graphical firing table of adjusted elevation below photomap range eliminates necessity for an accurate scale.

c. Connection survey. No survey is run. The connection survey is accomplished by registration.

d. Position area survey. Batteries are located by inspection or traverse. Short distances are paced; longer distances are taped on the run. Orienting lines are staked in. No attempt is made to determine the azimuth of the orienting lines, but if more than one orienting line is required, their relative directions are established by a directional traverse. The batteries are plotted on the photomap and their base lines drawn. When the registering battery reports its base angle, the base angles of the other batteries are computed by applying to the base angle of the registering battery the base point offsets (measured from the photomap) and any variation in the direction of the oriening lines. The altitudes of the batteries are determined as outlined in paragraph 298d.

301. EXAMPLE: BATTALION SURVEY; 1 HOUR AVAILABLE (fig. 139).

a. Mission. To mass the fires of the battalion, registration permitted.

b. Situation. The terrain is rolling. There are scattered woods throughout the area. The position area is not visible from the observation area. Numerous points in the battalion area and in the target area are identifiable on the photomap.

c. Survey operations.

(1) TARGET AREA. Point A and the base point are located by inspection. The length of the line AS is determined by the length of AB measured from the photomap. Target area base is oriented by an instrument reading to the base point. Battery B is registered on the base point. The registration includes the determination of a zero height of burst. An approximate photomap scale is determined by comparing the ground distance (obtained by pacing) with the photomap distance between points R and T. When the registration is complete, observers at all batteries and at point A are alerted, and Battery B fires a round above the base point by increasing the base point site and using the time setting which gave a zero height of burst at the base point. All observers orient their instruments on this burst. A second round is fired at the same setting and is assigned an arbitrary altitude (assume 500 yards). All observers measure the vertical angle

to this second burst (assume the vertical angle from point A is +30 mils). The photomap distance from point A to the base point is measured as 2500 yards which is converted to 2000 yards ground distance by the photo-ground relation formula. The altitude of point A = 500 yards — $(2 \times 30\ m\!\!\!/)$ = 440 yards. The altitudes of the batteries are computed in a similar manner.

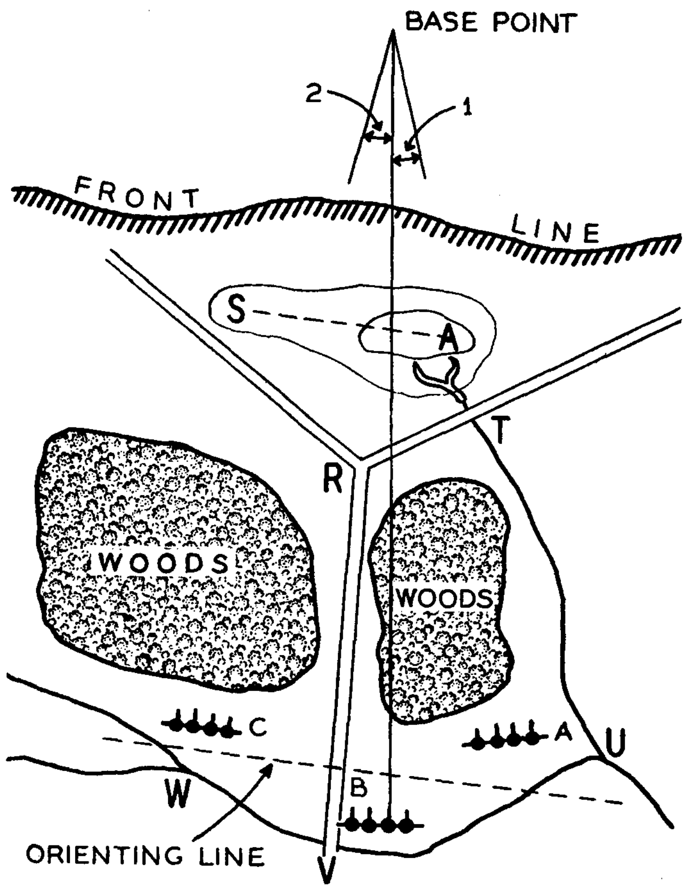


Figure 139. Battalion survey when a photomap is used; 1 hour available for survey.

(2) CONNECTION. None performed.

(3) POSITION AREA. Batteries are located by inspection using points U, V, and W. The orienting line is staked in on the ground. Base lines are drawn on the chart. When Battery B reports its base angle, base angles for Batteries A and C are computed by applying

offsets (angles 1 and 2) measured from the chart to the base angle of Battery B.

302. OPERATIONS OF HIGHER ECHELONS. The division is the largest unit which should attempt to mass its fires using a photomap as a firing chart. To mass the fires of all artillery of the division on a photomap, the division artillery survey section must furnish the photomap location, the ground location, and the altitude of a point visible to all battalions. This point is used by all battalions as a basis for establishing common vertical control on the photomap. In addition, it is desirable that division furnish the azimuth of the grid lines of the photomap, to facilitate use of metro data; and the photomap location, the ground location, and the altitude of a division artillery check point to be registered on by each battalion, in order to insure the massing of all battalions in the most critical section of the division zone. If possible, division artillery checks the accuracy of the photomap prior to its use as a firing chart. In any event, it is checked as soon as possible. If the check reveals the photo to be inaccurate, the grid sheet becomes the firing chart.

CHAPTER 9
NIGHT SURVEY

303. NIGHT SURVEY OPERATIONS.

a. General. Normally, all survey operations, with the exception of the location of points in the target area by intersection, can be performed at night. Night survey is performed in exactly the same manner as daylight survey. Necessarily, all work must be done with artificial light and consequently will be much slower. A night survey requires about three times as much time as would the same survey in daylight. Time and effort both, however, will be reduced if a daylight reconnaissance can be made. At night, lights must be used with extreme caution. Sound ranging, flash ranging, and radio position finding may furnish targets during darkness.

b. Traverse. At night, traverse may be begun from orientation (point of origin and line of direction) established during daylight, or after dark by astronomical means (par. 258), or by illuminating the initial control points if accessible. If initial orientation on the desired control points cannot be established during darkness, the correct relative positions of the legs of the traverse may be determined and tied in to a known direction during daylight. The head rodman bears greater responsibility for the selection of suitable advance stations at night because darkness limits the help which the instrument operator can give him. Longer sights sometimes can be made at night, because conditions may be such that a flashlight is more visible at night than a range pole or flag during daylight.

c. Resection. If sufficient points can be illuminated, resection may be performed at night.

d. Intersection (short base). If possible, the selection of the base and alinement of a stake for night orientation should be performed during the daylight reconnaissance. If no daylight reconnaissance is possible, orientation of the base on some accessible point may be used initially, but should be checked with a point in the target area as soon as daylight permits. Intersection in the target area at night is restricted to center of impact and high burst adjustments, and the location of the flash of firing weapons. However, when a suitable base can be established at night, other points in the target area can be located immediately after daylight.

304. USE OF INSTRUMENTS.

a. Aiming circle and transit. Most instruments are now equipped with night lighting devices which provide illumination for the cross hairs and the scales. When an instrument lacks night lighting devices, the recorder furnishes illumination for the cross hairs by holding a flashlight to one side, directing just enough light down the barrel of the telescope to make the cross hairs visible; too much light will blot out the object sighted upon. The instrument man uses a flashlight for reading the scale. In order to permit the instrument man to accustom his eyes to darkness so that he can view the cross hairs and move around the transit without disturbing it, an assistant does the recording.

b. Range poles and rods. The rodman provides a light upon which the instrument is sighted and upon which the tapeman may guide. An ordinary two-cell flashlight (with the beam at right angles to the barrel) fastened to the rod is just as satisfactory as any elaborate device. If, for short distances, the flashlight beam is too bright for the instrument man, the light can be dimmed by a handkerchief placed over the lens, by substituting a red lens for the clear one, or by removing the reflector from the light. The rodman must place his light directly over his station point and must make sure that it is aimed in the correct direction. The instrument man cannot see the rod at night and therefore cannot correct for its deviation from the vertical. Rodmen should be able to communicate with the instrument man by sending and receiving code signals with the flashlight.

c. Tape.

(1) At night the tapeman's duties are the same as during daylight. Artificial light should be dimmed so that the tapeman's eyes are continuously adjusted to semidarkness. He can then move along the survey line rapidly, without danger to himself or his equipment.

(2) To facilitate night taping, the ends of the tape (the zero and 100- or 300-foot marks) should be marked to make them more readily identifiable. A piece of white adhesive tape is satisfactory. The taping procedure is the same as in daylight with the exception that the head tapeman, after setting a pin, does not go forward until the rear tapeman has come up and identified the pin. A third man should assist the two tapemen in night taping. For horizontal taping, the extra man holds the light while the head tapeman sets his pin. When it is necessary to break tape, the extra man works with the tapeman who is using the plumb bob.

PART FIVE
MAP DATA AND CORRECTIONS

CHAPTER 1
DETERMINATION OF MAP DATA

305. GENERAL. This chapter covers the determination of basic data from firing charts. Generally, data taken from a firing chart, whether the chart consists of a map, a mosaic, or an improvised chart, are described by the term *map,* as *map data, map range, map shift,* and so on.

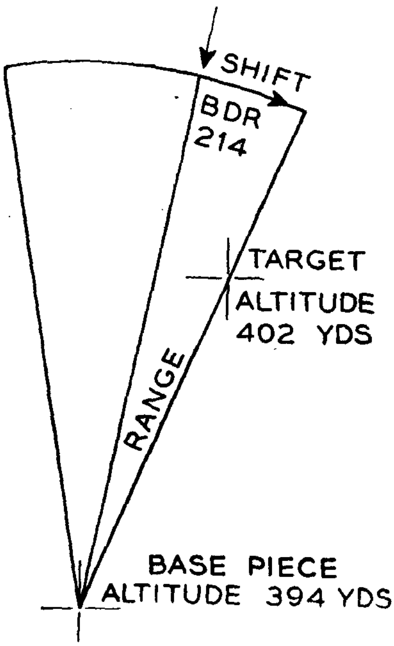


Figure 140. Map data.

Data may be prepared by the batteries, but usually are prepared by the battalion fire-direction center. The range-deflection fan normally is used for measuring range and shift (fig. 140). Altitudes are taken from the chart (par. 308).

306. DIRECTION. Measurements and computations are taken to the *nearest mil.* The shift is measured from the base line to the line, base piece-center of target. An additional shift is computed to center the sheaf on the target. Deflection may be computed from the coordinate location of base piece and target.

307. DEFLECTION DIFFERENCE. See paragraphs 90 and 97 to 100.

308. SITE. Angle of site equals the difference in altitude, in yards, between piece and target, divided by R. Altitudes are determined from a contoured map, by computation from instrument readings, from

BATTERY C
COORDINATES KX 5948
ALT OF BATTERY 400 YDS

DATA SHEET

TIME 1300 DATE 20 JAN 45

MAP DATA										COMMANDS										
CONC NO	COORDINATES	TIME: FROM	TIME: TO	TIME OF FLIGHT SEC	RANGE ELEVATION	DEFLECTION: CORR	MAP SHIFT SHIFT TO CENTER SHEAF	ALT (YDS) DIFF IN ALT HEIGHT OF BURST	ANGLE OF SITE COMP SITE	PROJ	CH	FUZE OR TIME	BD	DD	INDIV OR SHEAF CORRECTIONS	SITE	MF	ZONE	EL OR Q EL	REMARKS
Ck Pt 1	LN 4767				4280 321		L110	410 +10	+2 0	SH HE	5	Q AND Q M54 (T:18.4)	L110			302	No. 2 1		321	Adjusted data: Time 18.7 BDL 103 EL M48 330 EL M54 335
4	LN 1483	H-20 0510	H-16 0514	19	~~4380~~ 4280 321	R7	L193 R3	422 +22 +20	+8 +1	"	5	~~18.4~~ 18.7	~~L190~~ L183	ON #2 CL 2		309	B 8		~~321~~ 335	
17	BO 2408	H-15 0515	H-10 0520	25	5310 439	R4	R211 R14	384 -16 +20	+1 0	"	5	~~24.5~~ 24.8	~~R225~~ R229		Sheaf at 6500	301	B 1	11	~~439~~ 462	L23, ~~439~~ 462
10	KN 5302	H-5 0525	H-3 0527	15	3540 252	R9	L338 R4	406 +6' +20	+6 0	"	5	~~14.8~~ 15.0	~~L334~~ L325	ON #2 CL 2		306	B 4		~~252~~ 262	
8	AN 4656	H 0530	H+10 0540	20	4490 342	R7	R117 R3	388 -12 +20	+1 0	"	5	~~19.5~~ 19.8	~~R120~~ R127		Sheaf at 5500	301	B 1	8	~~342~~ 358	fire twice

NOTES: 1. Coordinates headed by letters are for a point designation grid; numerical coordinates are for a standard grid.

2. Times given are the times for the projectiles to *arrive on the target* and the time the fire must be lifted. The executive, by applying the time of flight, is responsible that the projectile arrive on the target at the specified time.

Figure 141. Data sheet.

EXPLANATORY NOTES FOR DATA SHEET

The data sheet in the figure above was prepared at battalion FDC. Firing chart was a photomap having point designation grid. A distance scaled (with 1/20,000 scale) on chart as 3260 yards was determined by survey to be 4120 yards on the ground. Battery front is 130 yards and pieces are irregularly spaced.

Areas. Conc 4, battalion will fire 1 *c* apart. Conc 17, Battery C must cover 300 yards in width by 200 yards in depth. Conc 10, battalion will fire, center range.

Concentration number. Assigned by S–3; entries should be made in the order of firing. Remarks such as 1 *c* apart, 200-yard zone, etc., may be made here.

Coordinates. Scaled by HCO (see Note 1).

Time. Announced by S–3; clock time is entered when H-hour is announced.

Time of flight. Given in seconds. Determined by computer (see Note 2).

Range. Measured on firing chart to the nearest 10 yards by the HCO.

Elevation. Determined by computer with GFT set with 228 (elevation for 4120) opposite 3260.

Deflection correction. The latest deflection correction.

Map shift. Measured on firing chart to nearest mil by HCO.

Shift to center sheaf. Determined by computer to place the sheaf on the proper portion of the target. As No. 2 is base piece, the sheaf is shifted to the right 17/*R*. For conc 17, the entire sheaf was moved to right half of the area to be covered initially (75/*R*) in addition to 17/*R*.

Altitude in yards. Determined from firing chart by VCO.

Difference in altitude. Determined by VCO from altitudes of the batteries and targets.

Height of burst. 20 yards is added when time fire is to be used.

Angle of site. Determined by VCO.

Complementary angle of site. Determined from firing tables by VCO; used when 0.5 mil or more. If the VCO determines the site in one operation by multiplying the angle of site by 1 plus the complementary angle of site factor, only one figure (the total site) need be entered, and the appropriate change is made in the column heading.

Projectile and charge. Announced by S–3.

Fuze or time. Announced by S–3. When time fire is used, the time is determined by the computer, and changed when new corrections are computed.

Base deflection. Measured shift, shift to center sheaf, and corrections, combined by computer.

DD. Deflection difference determined by computer.

Indiv or sheaf corrections. To be used when the pieces are irregularly dispersed laterally and the nature of the target or the method of attack indicate that a regular sheaf is desired.

Site. Angle of site and complementary angle of site, combined by computer.

Method of fire. Announced by S–3.

Zone. Determined by computer (based on announcement of S–3). For concs 17 and 18, 1 *c* to cover area in depth.

Elevation or quadrant elevation. Determined by computer. The elevation or quadrant elevation *includes latest corrections* for range.

Remarks. Announced by S–3. This column contains all pertinent information pertaining to firing the missions. Conc 17 is covered by firing through the zone in the right half, then shifting to the left half, and again firing through the zone. Conc 8 is fired the second time by repeating the elevation.

Latest corrections. Determined by computers based on registration or latest metro message. Combined with map data, and announced as new commands for time, shift, and elevation.

stereoscopic study of photos, by interpolation between known altitudes, or by a combination of these methods. Altitudes are taken from a contoured map to the nearest 5 feet, or nearest yard or meter. Altitudes computed by means of instruments, and interpolations between known altitudes, are taken to the *nearest yard.* For time fire, 20 yards are added algebraically to the difference in altitude. Angle of site and complementary angle of site are each computed to the *nearest mil.* The total site may also be computed in one operation by multiplying the angle of site by 1 plus the complementary angle of site factor.

309. RANGE. Measurements are taken to the *nearest 10 yards.* Corresponding elevations are taken to the *nearest mil.* When the firing chart has a scale different from that of the range-deflection fan, and registration has taken place, correction for discrepancy in scale is included in the total correction by comparison of adjusted elevation with map range. When registration is not used, the scaled range may be converted to true range by one of the methods given in paragraph 196, or the correction for difference in scale may be included in the setting for the graphical firing table. For the long ranges of heavy artillery, the true range may be determined by computation from coordinates of the base piece and target. It is essential that ranges to both check points and targets for transfers of fire be measured with the same instrument (usually range-deflection fan).

310. MAP DATA FOR PREARRANGED FIRES. Usually, map data for prearranged fires are tabulated in appropriate columns of the data sheet (fig. 141 above). Data for barrages and other complicated fires should be tabulated on the section data sheet (fig. 148).

311. STANDING BARRAGES. A standing barrage is a blocking fire to deny the enemy a particular route of attack. It is a portion of the coordinated defensive plan which includes mine fields, machine gun final protective lines, and mortar concentrations. A standing barrage is a defensive concentration or combination of defensive concentrations which may be delivered by battery or, more generally, by battalion. A standing barrage is ordinarily represented on the firing chart as a rectangle. The center line of the long axis is the line on which fire is desired, and is termed the barrage line.

312. VERIFICATION. Whenever possible, the barrage should be verified by firing. Necessary corrections based on this adjustment are made.

313. BATTERY BARRAGES. The following applies to the firing of a barrage by a battery, either individually or coordinated with other batteries. For maximum effect the length of the barrage line to be covered by a single battery should be equal to the distance between flank bursts

of an open sheaf. When necessary, the barrage line can be lengthened, but the effectiveness will be decreased. The maximum values shown in the following table should not be exceeded.

ITEM	75-MM		105-MM		155-MM
Size of battery	4 piece	6 piece	4 piece	6 piece	4 piece
Optimum length	100	150	100	150	200
Maximum length	200	300	200	300	400

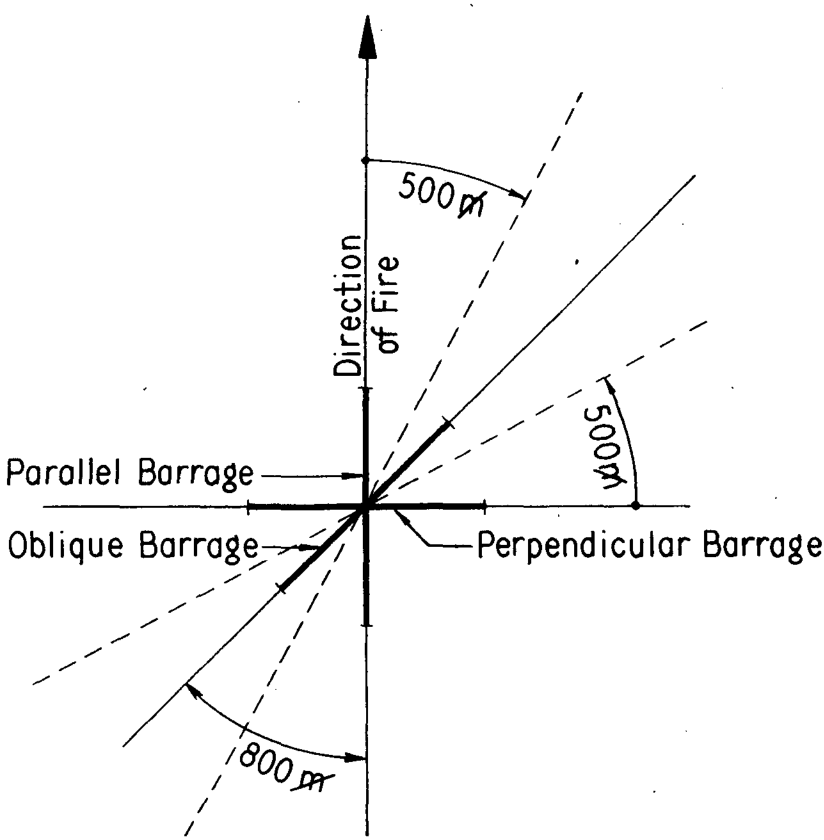


Figure 142. Angular limits of battery barrages.

When the length of the barrage line is equal to the optimum length, the barrage is fired as a single concentration. When the barrage line is longer than the optimum length, the barrage is fired as two concentrations.

a. Preparation of data. The barrage line may be perpendicular, parallel, or oblique to the line of fire. If the barrage line is within 500 mils of being perpendicular to the direction of fire, it is considered *perpendicular*. If the barrage line is within 500 mils of being parallel to the line of fire, it is considered *parallel*. Outside these limits the barrage is considered *oblique* (800 mils) to the line of fire (see fig. 142 above).

b. Barrage of optimum length (fig. 143). Map data for a barrage of optimum length are taken from the center point of the barrage line.

(1) DEFLECTION. The deflection shift is the sum of the map shift, the shift to center sheaf, and the latest deflection correction.

(2) DISTRIBUTION.

(*a*) A perpendicular barrage is fired with an open sheaf.

(*b*) A parallel barrage is fired with a converged sheaf.

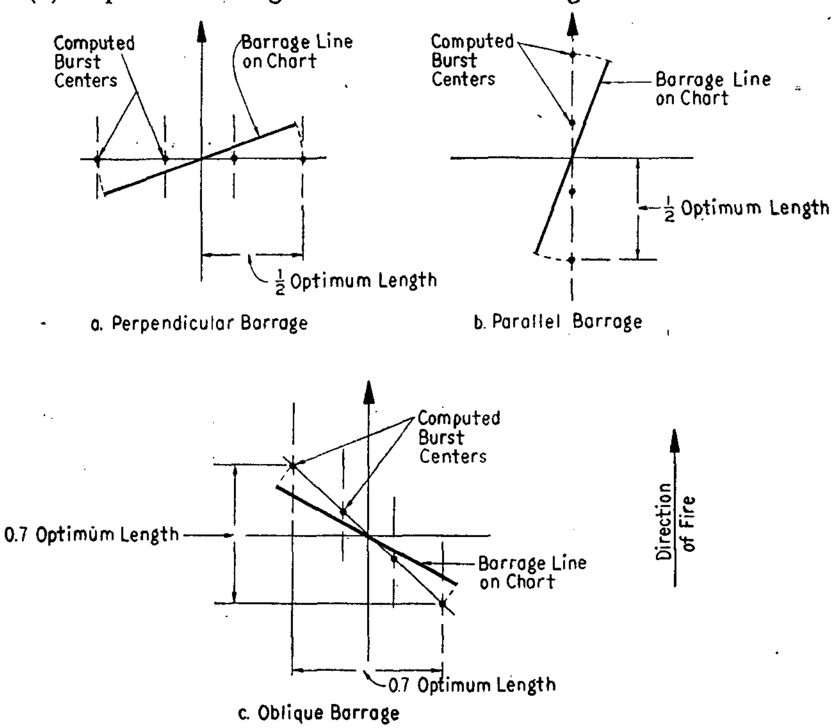


Figure 143. Typical battery barrages of optimum length (four piece battery).

(*c*) An oblique barrage is fired with a sheaf seven tenths the width of an open sheaf.

(3) METHOD OF FIRE. Fire is by volley at maximum rate.

(4) RANGE.

(*a*) In firing a perpendicular barrage, the range for all pieces is that to the center of the barrage line.

(*b*) A parallel barrage is fired with burst centers evenly distributed for range (fig. 143b).

(*c*) An oblique barrage is fired with burst centers evenly distributed for range (fig. 143c).

c. Barrages longer than optimum length. If the barrage line is longer than optimum length, it is fired as two separate concentrations, each of which is fired in the manner outlined above (fig. 144). Neither concentration is fired for longer than one minute before shifting to the other.

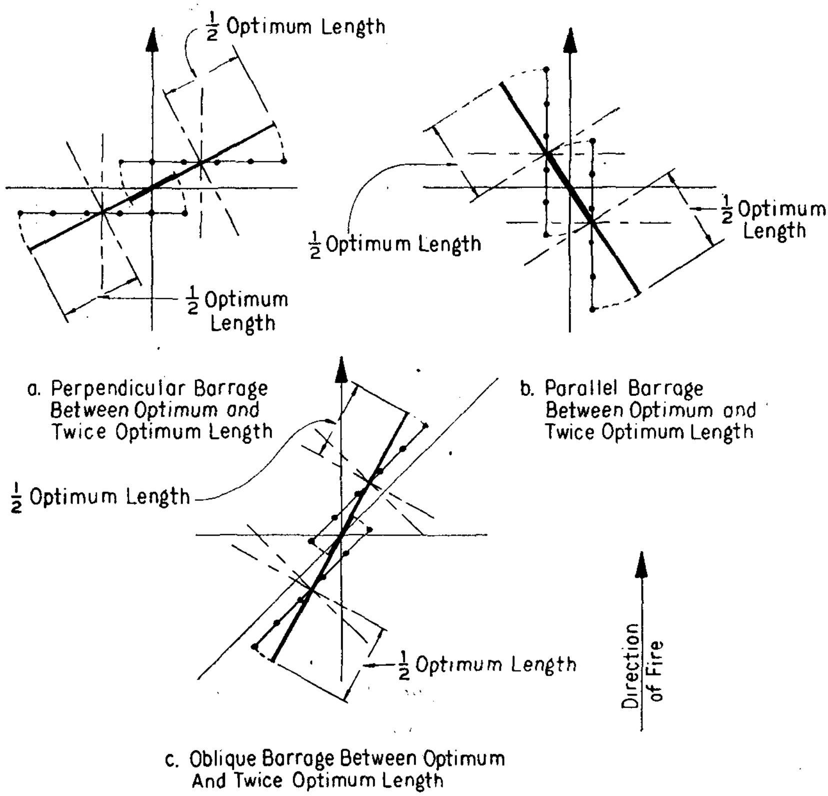


Figure 144. Typical battery barrages longer than optimum length (six piece battery).

314. BATTALION BARRAGES. The length of the barrage line indicates which of the following methods may be employed.

a. When the barrage line equals or exceeds three times the optimum length for a single battery, it is divided into three equal segments, each of which is assigned to one battery which fires its segment as described in paragraph 313. The maximum length of a battalion barrage should never exceed six times the optimum length for a battery barrage.

b. If the barrage line is between two and three times the optimum length for a single battery, the following method of attack is recommended. Divide the barrage line into two equal segments, and assign each segment to a battery. Each of these batteries then fires its segment as a single concentration using the superquick fuze and an open sheaf. The third battery is assigned the entire barrage line, and fires this as one time fire concentration. The battery with a direction of fire closest to perpendicular, parallel, or an 800 mil oblique to the barrage line is assigned this latter concentration. (See fig. 145.) The range spread and distribution for this battery are handled as follows.

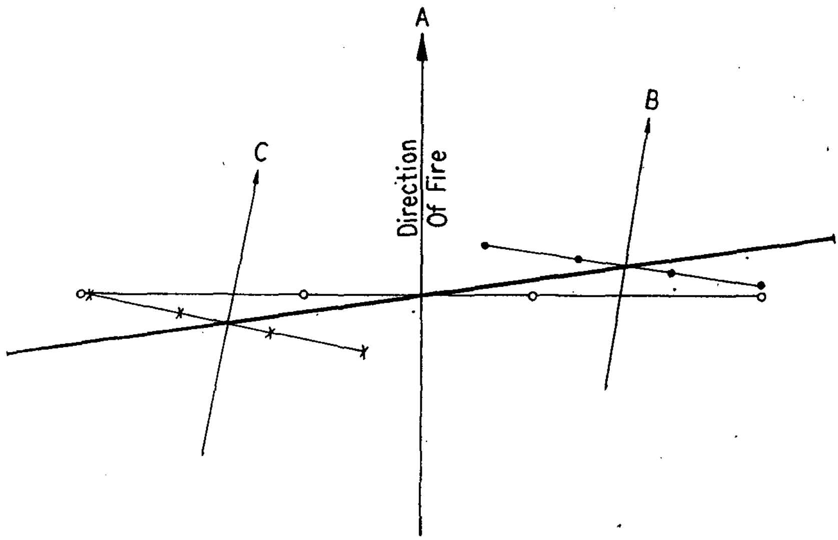


Figure 145. Typical mixed barrage (four piece batteries).

(1) For a perpendicular barrage the sheaf is opened to 3/4 the length of the barrage line for a four piece battery, and to 5/6 the length of the barrage line for a six piece battery. All pieces fire at the same range.

(2) For a parallel barrage the sheaf is converged. The barrage is fired with a range spread equal to 3/4 the length of the barrage line

for a four piece battery, and to 5/6 the length of the barrage line for a six piece battery.

(3) For an oblique barrage a sheaf equal to ½ the length of the barrage line is used. The range spread also equals ½ the length of the barrage line.

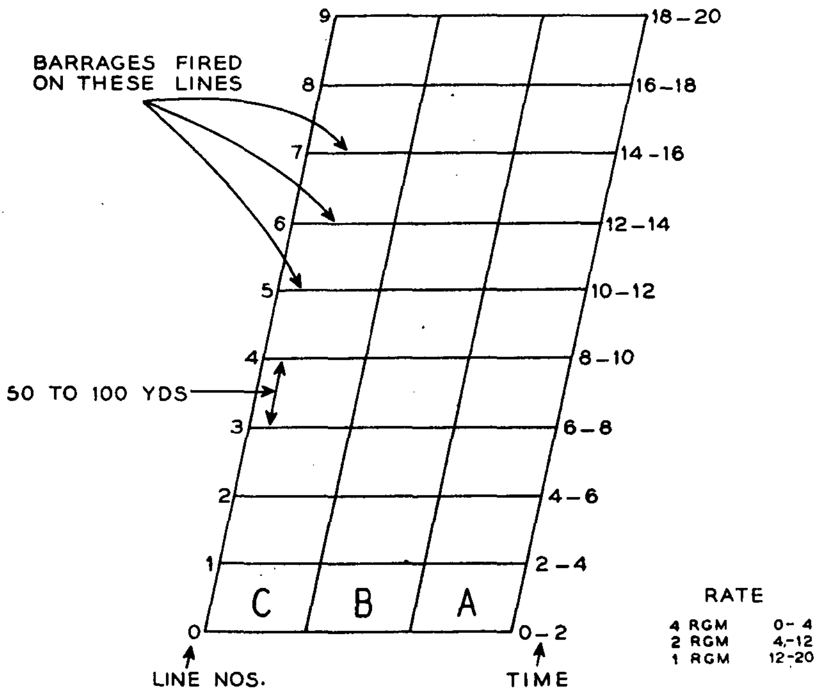


Figure 146. Overlay of a rolling barrage.

315. APPLICATION TO STANDARD CONCENTRATIONS. The principles of firing a parallel or an oblique barrage can be applied to the firing of any concentration if the terrain and situation so indicate.

316. ROLLING BARRAGE (fig. 146). A rolling barrage is represented on the firing chart as a series of barrage lines on which fire is to be placed successively. The distance between lines should be from 50 to 100 yards. The rate of roll is governed by the rate of the infantry advance. It may be from 2 to 10 minutes per 100 yards.

a. The data for each barrage line are prepared in the same manner as for a standing barrage. The length of the barrage line to be covered by a single battery is the optimum length (see par. 313). Data are prepared on data sheets (fig. 147) and sent to batteries. Batteries should

BATTERY B
COORDINATES 50.732-91.667
ALT OF BATTERY 402 YDS

DATA SHEET

TIME 1000 DATE 25 JAN 45

MAP DATA										COMMANDS										
CONC NO	COORDINATES	TIME FROM	TIME TO	TIME OF FLIGHT SEC	RANGE ELEVATION	DEFLECTION CORR	DEFLECTION MAP SHIFT SHIFT TO CENTER SHEAF	ALT (YDS) DIFF IN ALT HEIGHT OF BURST	ANGLE OF SITE COMP SITE	PROJ	CH	FUZE OR TIME	BD	DD	INDIV OR SHEAF CORRECTIONS	SITE	MF	ZONE	EL OR Q EL	REMARKS
Normal	54.31-91.67	On Signal 3 green Star			3580 267		R212 R3	430 +28	+8 +1	SH HE	4	Q	R215		70 yd SHEAF @ 3500	309 #1 U 3 #2 U 1 #3 D 1 #4 D 3	B(4)		267	R 13 UI 272 Fire Three Times
Barrage		Rockets			3630 272		R225 R3	434 +32	+9 +1											

a

BATTERY C
COORDINATES 33.116-77.771
ALT OF BATTERY 400 YDS

DATA SHEET

TIME 1620 DATE 28 JAN 45

MAP DATA										COMMANDS										
CONC NO	COORDINATES	TIME FROM	TIME TO	TIME OF FLIGHT SEC	RANGE ELEVATION	DEFLECTION CORR	DEFLECTION MAP SHIFT SHIFT TO CENTER SHEAF	ALT (YDS) DIFF IN ALT HEIGHT OF BURST	ANGLE OF SITE COMP SITE	PROJ	CH	FUZE OR TIME	BD	DD	INDIV OR SHEAF CORRECTIONS	SITE	MF	ZONE	EL OR Q EL	REMARKS
Normal Barrage	33.14-80.99	On Signal 3 white Star Rockets			3220 226		L 61 R 10	415 +15 +20	+11 +1	SH HE	4	11.7	L51		300 yd SHEAF @ 3000	312	B(12)		226	

b

Figure 147. Barrage data sheets.

EXPLANATORY NOTES FOR BARRAGE DATA SHEETS

The data sheets in the figures above were prepared at battalion FDC. The firing charts were grid sheets (1/20,000 scale).

a. Figure 147a (four piece battery).

(1) *Size.* The normal barrage assigned to the battalion is 500 yards in length. Battery B is assigned the center 165-yard portion. This is an oblique barrage and will be fired as two concentrations.

(2) *Map data.* Map data were determined for the center of each concentration. The centers are one half the optimum length (50 yards) in from either side of the barrage line.

(3) *Shift to center sheaf.* Since barrage is oblique, the sheaf to be used is 70 yards in width, and it must be shifted to the right 12 yards for centering.

(4) *Sheaf corrections.* With the pieces irregularly dispersed laterally, the executive may be directed to form the desired regular sheaf.

(5) *Site.* Site corrections are given for each piece to obtain proper range spread for an oblique barrage. These are combined with the corrections for calibration and for echelonment in depth in preparation of the section data sheet.

(6) *Method of fire.* The number of volleys to be fired prior to shifting is not greater than that which can be fired in 1 minute.

(7) *Remarks.* The changes in data necessary to shift the fire to the second half of the barrage are entered here. The remark "Fire three times" indicates that both concentrations are to be fired alternately three times.

b. Figure 147b (six piece battery).

(1) *Size.* The normal barrage assigned to the battalion is 400 yards in length, and is to be fired as a mixed barrage. Battery C is to fire the time concentration. The barrage line is approximately perpendicular to the direction of fire.

(2) *Map data.* Map data were determined for the center of the battalion barrage line.

(3) *Sheaf.* The sheaf to be used is 330 yards wide ($(5/6) \times 400$). The sheaf must be shifted 33 yards to the right for centering.

c. Special corrections. When the S–3 decides that the situation warrants the use of special corrections, these will be entered on the data sheet by the computer.

d. Other notes. For further notes on the preparation of the data sheet see figure 141.

prepare section data sheets for each piece (see fig. 148). Latest corrections are applied immediately prior to firing. Once firing has begun, corrections are not changed.

b. Although a rolling barrage is set up on a time schedule, its rate of advance can be controlled to conform to the rate of advance of the infantry. The barrage can be speeded up, slowed down, or halted on a line. It should not, however, be moved back without careful coordination with the infantry commander concerned.

SECTION DATA SHEET

4TH SECTION. BATTERY B AMMUNITION LOT Sh HE LS-5-1

CONC OR BOUND NO	TIME		CH	FUZE OR TIME	BD SHIFT	DD OR INDIV SHIFT	2800	SITE	METHOD OF FIRE	RATE RGM	EL ~~OR Q EL~~
	FROM	TO					DF				
0	0 1420	4 1424	6	Q	R211		2589	302	B 1	4	374
1	4 1424	8 1428			R200		2600	303		2	378
2	8 1428	12 1432			R189		2611	305			383
3	12 1432	16 1436			R179		2621	305			388
4	16 1436	20 1440			R169		2631	305			393
5	20 1440	24 1444			R159		2641	306			398
6	24 1444	28 1448			R149		2651	306			403
7	28 1448	32 1452			R140		2660	306			408
8	32 1452	40 1500			R130		2670	306			413
9	40 1500	44 1504			R121		2679	306			419
10	44 1504	48 1508			R112		2688	305			425
11	48 1508	52 1512			R104		2696	306			430

Figure 148. Section data sheet for a rolling barrage.

CHAPTER 2
DETERMINATION OF CORRECTIONS BY REGISTRATION

317. GENERAL. The most precise data result when map data are corrected by registration. A transfer of fire (*K*-transfer) consists of registration on a point whose position relative to the piece and targets is known, and the determination from this registration of corrections to be applied to the map data for the targets. The adjusted data are those determined by precision registrations (see PART THREE); or they are the piece settings and time setting actually used for a center of impact or high burst registration. In case the site used on the piece during registration does not agree with the true site, the true site (including complementary angle of site) is subtracted from the adjusted *quadrant* elevation to determine the adjusted elevation. True site is determined from the firing chart if altitude control is available; if not, it may be determined approximately by firing.

318. DETERMINATION OF SITE BY FIRING. Registration on the base point or check point must first be made to determine adjusted deflection, adjusted time, and adjusted quadrant elevation. At the conclusion of the registration the commands: OBSERVE HIGH BURST, MEASURE SITE, THREE ROUNDS, followed by the adjusted data are sent to the executive. The executive increases the site by the amount necessary to place the bursts above the intervening mask, fires the rounds, and reports the observed angle of site to the mean burst center, and the quadrant elevation at which the bursts were fired. The site from the base piece to the point of registration is determined as in the example below.

Adjusted data from registration:

Charge 5

Time 14.3

Quadrant El 240.

Reports from executive:

Observed angle of site +30.

Quadrant elevation at which rounds were fired 280.

Angle of site, +30, plus complementary angle of site, +2, (*i.e.*, $+30 \times .06$) = site +32.

280 − 32 = adjusted elevation 248 (adjusted elevation to mean burst center).

The site to the point of registration is determined by subtracting the adjusted elevation from the adjusted quadrant elevation.

Site = 240 − 248 = −8 mils.

Adjusted data: Time 14.3, Site −8, Elevation 248.

319. DEFLECTION CORRECTION.

a. The deflection correction at check point range is determined by comparing map shift and adjusted deflection. For example:

(1) The map shift to a check point is BDR 265 and the adjusted deflection from a precision registration on the check point is BDR 257. The deflection correction is left 8.

(2) A center of impact (or high burst) registration is fired with a deflection of BDL 350 set on the piece. The shift from the base line to the plotted location of the resulting center of impact is BDL 354. The deflection correction is right 4. If instrument direction has been recorded following the registration, direction may be checked later using instrument direction.

b. The base piece may be laid on base deflection by making a precision adjustment on the base point. This procedure is applicable when direction has not been given to the pieces by survey. When the adjustment is completed, base deflection is recorded without changing the position of the tube. The deflection correction at the base point is zero. Following the registration, instrument direction may be recorded (par. 72) for future use.

c. In case direction has not been given to the pieces by survey, direction may be established by having the location of a center of impact reported by an air observer or a ground observer having a commanding view of the area. (The ground observer should use an instrument and reference point to insure accuracy of location.) The following procedure is applicable: The piece is laid in the desired direction, and the center of impact registration is fired. Base deflection is recorded without changing the position of the tube. The deflection correction at the center of impact is zero.

320. ELEVATION CORRECTION.

a. Computation of *K*. Map range to a target is corrected by use of the assumption that the ratio of adjusted range to map range is a constant, known as *K*. In practice, *K* is expressed as plus or minus so many yards per thousand yards. It is determined as follows: Map range is subtracted from adjusted range (range corresponding to adjusted elevation). The difference is divided by *R*.

b. Examples.

(1) Materiel, 105-mm howitzer, M2, firing charge 4. Map range to check point = 4620 yards. Adjusted elevation = 395. Range corresponding to elevation 395 = 4820. $K = \dfrac{(4820 - 4620)}{4.6} = +43$ (or 44) yards per 1000 yards.

(2) Materiel, 155-mm howitzer, M1, firing shell HE M107, charge 6. A center of impact registration is fired with a quadrant elevation of 270. The map range to the plotted mean location of the rounds is 7920. Site is +17 mils. Complementary site is $17 \times .06 = 1$ mil. Elevation is $270 - (17 + 1) = 252$. Range corresponding to 252 is 7460.

$$K = \frac{(7460 - 7920)}{7.9} = -58 \text{ yards per 1000 yards.}$$

c. Graphical firing table. To set up the GFT for determination of corrected elevation, the hairline is set over the map range, and a gage line is marked on the indicator over the adjusted elevation. Thereafter, the gage line shows corrected elevation for any range under the hairline.

321. TIME CORRECTION.

a. Registration. The time correction at check point range is determined from a registration by comparing the adjusted time with the firing table value of time for the adjusted elevation. Examples:

(1) Materiel, 105-mm howitzer M2, firing charge 5. The following data have been determined by precision registration on a check point:

Adjusted time	17.7
Adjusted elevation	292.

The firing table value of time corresponding to elevation 292 is 16.9. The time correction at check point range = +0.8 second (*i.e.,* 17.7 − 16.9).

(2) Materiel, 105-mm howitzer M2, firing charge 5. A high burst registration has been fired with the following settings:

Site	330
Elevation	280
Time	16.3.

From the mean vertical angle measured by an observer, angle of site has been computed by the mil relation and found to be +19 mils. Complementary angle of site = $(+19) \times (+.08) = +2$ ₥. Site = 19 ₥ + 2 ₥ = +21 ₥.

$$\begin{aligned} \text{Adjusted quadrant elevation} = 280 + 30 = {} & 310 \\ \text{Site} = {} & -21 \\ \hline \text{Adjusted elevation} = {} & 289 \end{aligned}$$

Time corresponding to *adjusted* elevation (289) = 16.8. Time correction at check point range = −0.5 second (16.3 − 16.8).

b. Time *K*. The time correction is divided by map range to check point (in thousands of yards) to obtain time K. In subparagraph a (1) above, time correction = +0.8 second; map range = 5270 yards; time $K = +0.8 \div 5.3 = +0.15$ second per thousand yards. In subparagraph a (2) above, time correction = —0.5 second; map range = 4870 yards; time $K = -0.5 \div 4.9 = -0.10$ second per thousand yards.

c. Graphical firing table. To set up the GFT for the determination of corrected time, set the adjusted elevation gage line over the adjusted elevation, then mark the adjusted time gage line on the indicator over the adjusted time. In the example of subparagraph a (1) above, with the charge 5 GFT, the adjusted elevation gage line is set over elevation 292 and the adjusted time gage line is marked over time 17.7. In the example in subparagraph a (2) above, the adjusted elevation gage line is set over elevation 289, and the adjusted time gage line is marked over time 16.3.

The time correction is represented graphically by the distance between the two gage lines, and is independent of the position of the hairline.

CHAPTER 3
DETERMINATION OF CORRECTIONS FROM A METRO MESSAGE

322. GENERAL. When firing data are corrected for conditions not standard by means of the firing tables, the data are called *map data corrected.* These nonstandard conditions include weather, as given by the metro message; temperature of powder; weight of projectile; velocity error (*VE*); and rotation of the earth for long range weapons. Unknown errors, such as errors in survey, can be corrected only by adjustment or registration. Metro corrections are computed for an arbitrary point called a metro check point in the center of the target area for the charge used, or for a specific target. Time correction cannot be determined from a metro message.

323. SOLUTION OF THE METRO MESSAGE.

a. General. The firing tables for each weapon give the type of message to be used, a wind components table, standard conditions, unit effects, and detailed explanation of the computation of data using the metro message. Direction and range to metro check points are taken to multiples of 100.

b. Procedure. A systematic procedure to speed the solution is as follows:

(1) List all pertinent known values, to include: shell, charge, range to metro check point or target, altitude (and latitude) of battery, direction of fire, weight of projectile, powder temperature, and *VE* (par. 324) (from ammunition data card, calibration, or previous registration).

(2) From table B, part 2, of the firing tables, obtain change in velocity due to change in temperature of powder.

(3) From tables D and E, part 2, of the firing tables, obtain range and deflection effects due to rotation of the earth for the latitude of the battery (long range weapons only).

(4) From table A, part 2, of the firing tables, obtain line number of message to be used and standard values and unit effects for drift, lateral wind, weight of projectile, *VE*, air temperature, rear wind, and air density.

(5) From the proper lines of the metro message, check the time that the message was completed, to insure receipt of latest message and the

proper type of message. Obtain altitude of the meteorological datum plane (MDP), wind direction and velocity, ballistic density and air temperature at MDP.

(6) Compute chart direction of wind and relative altitude of battery and MDP.

(7) From part 1 in the firing tables, obtain wind components and corrected density and temperature.

(8) Subtract standard values from actual values; multiply differences by respective unit effects, and take totals.

c. Example. Materiel, 105-mm howitzer M2. Altitude of battery, 290 yards. Metro check point for charge 4: *Y*-azimuth 2800, range 4000 yards. Executive has reported powder temperature 38°; weight of projectile, one square. Old *VE*, 27 *f/s* (par. 324).

The following metro message (new type) has been received:

MESSAGE		(*Call sta*)	(*Alt MDP*)	(*Time message complete*)	(*Type*)
MIF 12 09303	→	MIF	12	0930	3
056 15 98337					
156 16 97737					

		(*Line No.*)	(*Wind direction*)	(*Wind velocity*)	(*Density*)	(*Ballistic temp*)
257 16 97335	→	2	57	16	97.3	35
358 17 97032						
456 20 96532						

Solution: charge 4, range 4000:

Line of message to be used: 2 57 16 973 35

Correction of density: $3 \times 0.3 = +0.9$

Corrected density: 98.2%

Correction of temperature: $3 \times 0.2 = +0.6$, use $+1$

Corrected temperature: 36°

Chart direction of wind: $5700 - 2800 = 2900$

Drift effect . . . . R 4 mils

Lateral wind effect L $0.29 \times 16 =$ L 5 mph

L 5×0.2 . . . . L 1 mil

Deflection effect . . . . R 3 mils

Range wind effect $+0.96 \times 16 = +15$ mph.

	ACTUAL VALUES	STANDARD VALUES	VARIATION FROM STANDARD	UNIT EFFECT	PLUS	MINUS
Weight of Projectile			− 1	−38	38	
Powder Temperature	38°		−10 *f/s*	+8.1		81
Old *VE*			−27 *f/s*	+8.1		219
Air Temperature	36°	59°	−23	−0.1	2	
Rear Wind			+15 mph	+1.4	21	
Density	98.2%	100%	− 1.8%	−4	7	
					68	−300
						+ 68
Range effect (yards) =						−232

d. Corrections. By reversing the direction or sign of the effects determined in subparagraph c above, corrections are obtained. The deflection correction is left 3 at range 3768. The range correction is +232 yards at range 3768. The corrected elevation for range 3768 equals 307 (the tabular elevation for range 4000). Metro $K = +61$ yards per 1000 yards, and is obtained by dividing the range correction by 3.8 (R).

e. Corrections for long range weapons. The firing tables for certain long range weapons give the range and deflection effects of rotation of the earth. These effects may be combined with the effects due to nonstandard conditions of weather and materiel, and the corrections applied in the same manner.

f. Graphical firing table. The range effect is added algebraically to the range to metro check point. The hairline is set over the resulting sum and a gage line is drawn over the elevation corresponding to the metro check point range.

324. VELOCITY ERROR (*VE*).

a. When metro data have been in use and a registration is fired, corrections determined from the registration are put into effect. After a change in weather conditions, registration corrections usually fail. If registration is not practicable, it is necessary to use metro data again.

b. A comparison is made between the corrections determined by metro and those determined at approximately the same time by registration. The cause of discrepancy between them presumably is unknown. In order to provide more accurate metro corrections if it becomes necessary in the future to revert to their use, it is assumed that

the unknown causes may all be attributed to a variation from standard muzzle velocity. The amount of this variation is computed, and it is introduced into future metro computations as the *VE*, as illustrated in paragraph 323c.

c. In the event that metro corrections are computed with the old *VE* included, registration again may indicate that there still is a discrepancy between metro corrections and registration corrections. This residual discrepancy again is reduced to terms of *VE*, and since it measures the amount by which the old *VE* was in error, it is known as the *VE change*. When added algebraically to the old *VE*, it gives the new *VE*, which is used in subsequent metro computations, becoming the old *VE* when subjected to further modification.

d. *VE* and *VE change* must be determined and applied judiciously. The following principles govern:

(1) *VE* is applicable to the ammunition lot, the charge, the existing survey, and, to some extent, to the range at which determined, and to the proximity of the metro check point to the registration check point. Failure of metro messages to represent exactly the existing weather conditions also contributes to the *VE*, but since minor metro errors usually can neither be foreseen nor detected, the metro messages must be assumed to be correct.

(2) An old *VE* is not used if determination of a new *VE* is to follow a change of ammunition lot, but it is not discarded. The new *VE* (based on the above) is used as long as the new conditions prevail. Upon return to the old conditions (ammunition lot), the old *VE* is assumed to be more correct.

(3) A *VE* determined for a given charge is applicable only with that charge.

(4) Climatic and storage conditions may cause a change in the standard velocity for all ammunition in a particular area. When extensive firing of different weapons and ammunition lots shows this change in velocity to be consistent in amount of variation, this *VE* may be used in initial metro computations until registration permits more accurate data.

e. The following are illustrative examples:

(1) 105-mm howitzer, M2, firing charge 5. Ammunition data card shows standard velocity. Metro computation for range 5500 shows an effect of plus 192 yards. Registration (with charge 5), simultaneous with weather conditions that prevailed when the metro message was computed, gives a *K* of minus 26 yards per 1000 yards; this is an effect of $26 \times 5.5 = 143$ yards. Metro data was plus 49 yards (*i.e.*, $192 - 143$) in error. At 5500, effect of 1 *f/s* variation in muzzle velocity is 7.7 yards. *VE* is $49/7.7 = 6$ *f/s*. Since *VE* is effect (not correction), and since

shells fell short of the point predicated by metro, the sign is minus. Thereafter a *VE* of minus 6 *f/s* is used in computation of metro corrections.

(2) Subsequent simultaneous registration and metro computations (the latter including the old *VE* of minus 6 *f/s*) are again compared, and show a *VE change* of minus 4 *f/s.* In this case, the registration check point was closer both in range and deflection, to the metro check point. It is, therefore, assumed that the second comparison is more valid than the first. Old *VE* is combined with *VE change* to give a new *VE* of minus 10 *f/s,* which is used thereafter.

(3) A subsequent third comparison, using the same ammunition lot, and the same check points as in (2) above, gives a *VE change* of —6 *f/s.* Since it is impossible to determine whether the comparison in (2) is more valid than that in (3), a mean of the old *VE* (—10 *f/s*) and new VE (—16 *f/s)* is accepted for future use.

(4) A new ammunition lot is being used. The ammunition data card indicates that for charge 5, the velocity will be 5 *f/s* above standard. Until *registration permits determination of a more acceptable VE,* +5 *f/s* is used.

(5) The battery changes position, but goes back to the same ammunition lot used in (3) above. The old *VE* (—13 *f/s*) is used.

(6) From a registration prior to dark, a *VE* of +15 *f/s* has been computed for supercharge with the 155-mm gun M1. Flash reducer is to be used with a *VE* of +10 *f/s* with normal charge, and +25 *f/s* with supercharge (obtained from ammunition data card). Prior to registration with flash reduced, a *VE* of +40 *f/s* (*i.e.,* (+25) + (+15)) is used for supercharge.

325. DEFLECTION CORRECTION CHANGE.

a. When metro corrections have been in use, registration permits a comparison of metro and registration deflection corrections. The difference between the two is the *deflection correction change.* It is the amount by which the metro deflection correction must be modified to give the registration deflection correction, for example:

Metro deflection correction = L 6
Registration deflection correction = L 9
Deflection correction change = L 3.

It is used to modify all subsequent metro deflection corrections, or until additional registrations provide what appears to be a better value.

b. Until further metro comparisons with new registrations for different charges and check points indicate otherwise, the deflection correction change is used throughout the zone of fire.

CHAPTER 4
APPLICATION OF CORRECTIONS

326. GENERAL. Corrections are assumed to be valid within transfer limits; namely, within ranges 1500 yards greater or less than check point range, and within 400 mils in direction right or left of the check point, up to 10,000 yards; for longer ranges, corrections apply within 2000 yards of the check point for range and 4000 yards for deflection; they should be used as a guide for a particular firing chart, charge, and condition of weather. Registration corrections also apply to a particular lot of ammunition. *VE* corrections are assumed to be valid throughout the range of the charge for which computed. Check points usually are chosen so that any point in the target area will be within transfer limits of at least one check point; nevertheless, a minimum number of sets of corrections is desired (figs. 149 and 150). (For high angle fire, see paragraph 149b (5).)

327. DEFLECTION CORRECTION.

a. For a range materially greater or less than check point range, differences in drift must be considered. Drift effect is always to the right, and (except in high angle fire) increases with an increase in range. The application of differences in drift may be learned from a study of the following examples:

(1) Materiel, 155-mm howitzer M1, using charge 4. Deflection correction (from registration) = L 3 at check point range of 6000 yards.

Range	*Drift*	*Difference in Drift*	*Deflection Correction*
6000	6	0	L 3
7000	8	L 2	L 5 (L 3, L 2)
5000	4	R 2	L 1 (L 3, R 2)

(2) Materiel, 155-mm howitzer M1, using charge 3. Deflection correction = R 2 at check point range of 5000.

Range	*Drift*	*Difference in Drift*	*Deflection Correction*
5000	7	0	R 2
6500	14	L 7	L 5 (R 2, L 7)
5700	9	L 2	0 (R 2, L 2)
4000	4	R 3	R 5 (R 2, R 3)

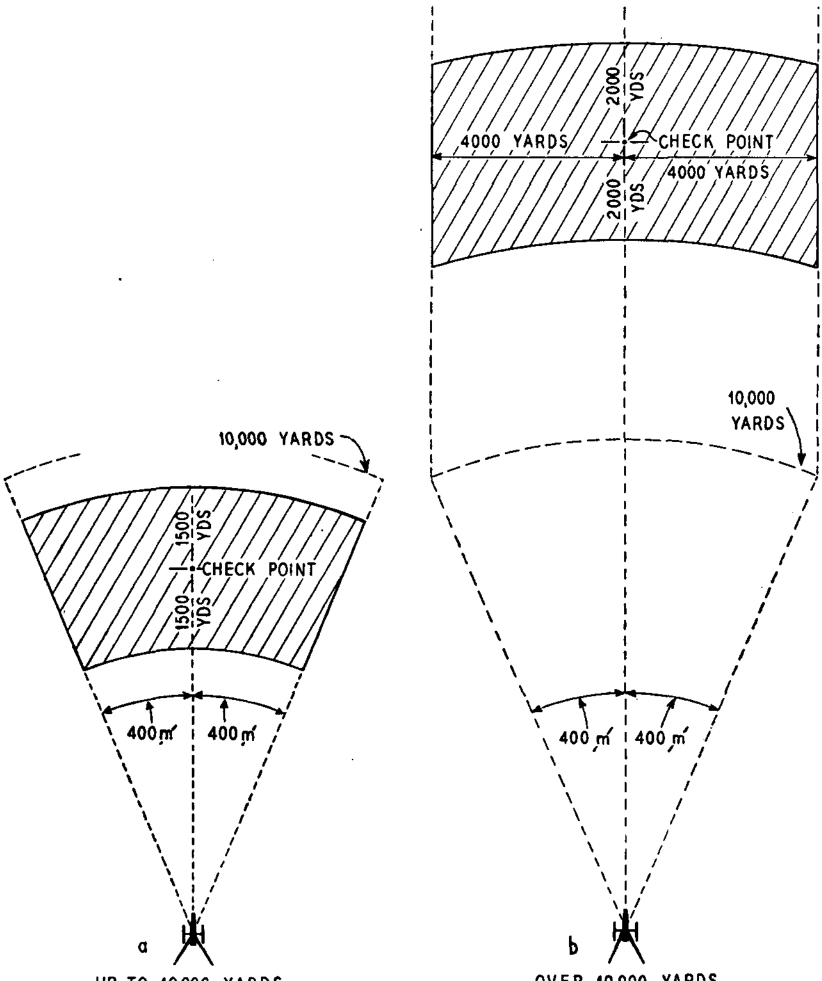


Figure 149. Transfer limits.

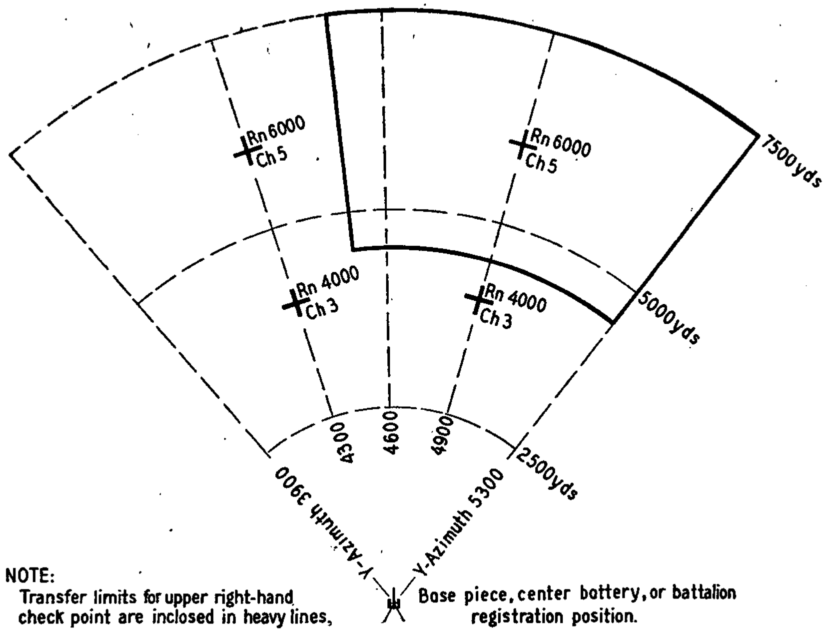


Figure 150. Ideal location of check points for use with 155-mm howitzer.

b. A lateral wind may have considerable effect on the path of a projectile. The differences in the effects of the wind within transfer limits are taken into consideration as shown in paragraph 347.

c. The corrections may be placed on a *deflection correction scale* (fig. 151). The corrections are shown at check point range, and are computed throughout transfer limits for each point at which the drift changes. Ranges at which these drift changes occur are shown to the nearest 100 yards opposite the corrections, except that the ranges already appear on the range-deflection fan, and are not required if the scale is drawn in its correct location on the fan. The deflection correction for any target is read opposite the appropriate range.

d. When metro data are used, the deflection correction for individual targets may be determined either from the deflection correction scale or from a solution of the metro message. Deflection correction change should be included if known (par. 325).

e. In high angle fire the drift changes very rapidly within each charge, and it is consequently impracticable to show the corrections throughout transfer limits at each point where the drift changes. The appropriate drift is therefore stripped out of the deflection correction for each registration, and one correction (which does not include drift)

is noted for each charge. Then in determining the deflection correction for any target, the drift correction appropriate to the elevation to be fired must be added algebraically to the above correction.

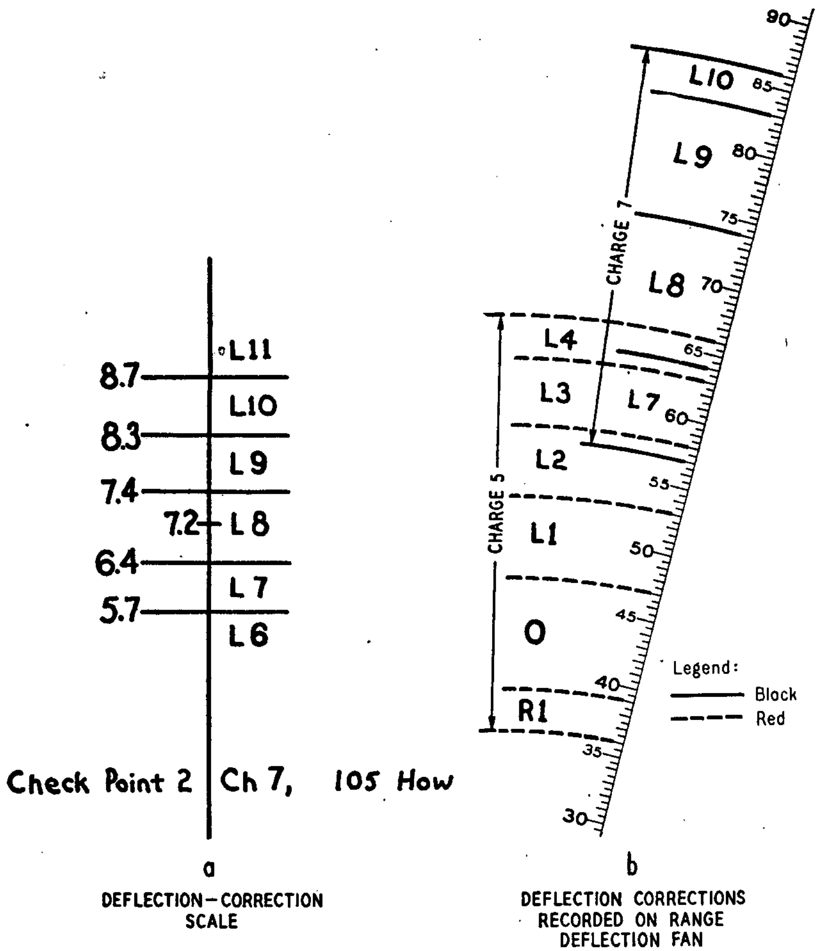


Figure 151. Methods of recording deflection corrections.

328. ELEVATION CORRECTION.

a. The determination of corrected elevation for a transfer is a reversal of the process used in determining a *K*. To determine the corrected elevation, multiply *K* by map range in thousands of yards to obtain the range correction; add the correction algebraically to map range, and from the firing tables determine the elevation corresponding to the corrected range. For example: materiel, 105-mm howitzer, using charge 7; $K = +24$ yards per 1000 yards; corrected range for a

target at range 9360 yards = 9590 (*i.e.,* 9360 + (24 × 9.4)); corrected elevation = 412 (tabular value for 9590 yards). Corrected elevations may be computed for each target, or determined from an elevation correction scale.

b. When metro data are used, the corrected elevation may be determined either by using metro *K* as in subparagraph a above, or by solution of the metro message for each target. The latter procedure is appropriate for prearranged fires when targets are widely scattered or when there is ample time for computation. When time is limited, use metro *K* for targets within transfer limits of the point for which the metro corrections were computed.

c. After a registration has been fired and unobserved fire must be delivered on a target outside of transfer limits, *VE* determined from registration should be applied to the solution of the metro message for that target.

d. With the GFT set up for the determination of corrected elevations, the corrected elevation is read under the adjusted elevation gage line when the hairline is over the map range. In the example in subparagraph a above (charge 7, range 8560, elevation 355), the corrected elevation for a target at range 9360 yards is read as 412.

329. TIME CORRECTION.

a. Computed. For any range within transfer limits, the time correction = time *K* × *R*. This correction is applied to the firing table value of the time corresponding to the *corrected* elevation. For example, assume that a 105-mm howitzer battery, firing charge 5, determines a time *K* = +0.15 second per 1000 yards, and *K* = —44 yards per 1000 yards; a *K* transfer is to be fired at map range 6310 yards

Corrected range (6310 — (44 × 6.3))	= 6030 yards	
Elevation for corrected range	= 372 mils	
Time corresponding to elevation 372		= 21.0 sec
Time correction = +0.15 × 6.3		= +.9 sec
Corrected time		= 21.9 sec

b. Time correction scale. To facilitate the determination of time correction for a number of targets within transfer limits, a time correction scale similar to the deflection correction scale, figure 151, may be constructed.

c. Graphical firing table. The GFT has been set up for the determination of corrected time; the hairline is set over the map range, and the corrected time is read under the adjusted time gage line. In the example in subparagraph a above (charge 5; range 5270, elevation 292;

adjusted time gage line over 17.7), the corrected time is read as 22.1. A discrepancy between computed time setting and time setting appearing on the GFT will result from the fact that the time corrections determined by computation and determined from the GFT are not based on the same mathematical assumptions. The discrepancy usually is small. Experience shows that there is little choice regarding the comparative correctness of the two methods.

330. GRAPHICAL FIRING TABLE. For detailed instructions on use and nomenclature of graphical firing tables, see TM 9–524 for the 12-inch graphical firing table, and TM 9–526 for the 16-inch graphical firing table.

PART SIX
FIRE DIRECTION; MASSING OF FIRES

CHAPTER 1
FIRE DIRECTION, GENERAL

Section 1. GENERAL

331. FIRE DIRECTION. Fire direction is the tactical and technical employment of the fire power of one or more artillery units to bring fire to bear at the proper place at the proper time in the appropriate volume. Effective fire direction depends upon proper organization for combat, reconnaissance, survey, communication, liaison, observation, and intelligence.

332. OBJECT OF METHODS USED. The methods employed in fire direction must provide for:

a. Continuous and accurate fire support under all conditions of weather, visibility, and terrain.

b. Flexibility, sufficient to engage all types of targets over a wide area.

c. Prompt massing of fires of all available units in an area where range limitations permit.

d. Prompt distribution of fires simultaneously on numerous targets within the same limitations as in subparagraph c above.

333. SOURCES OF TARGETS. Targets for field artillery may be located and reported by the supported troops or by liaison personnel with those troops; by field artillery ground or air observers; by personnel of the field artillery observation (sound and flash) battalion; by adjacent or higher headquarters (including radio position finding stations and by air and ground reconnaissance agencies), by analysis of photos and knowledge of enemy activities, and through prisoners of war and civilians. A description of the target and request or order for fire may accompany the report. The person reporting the target may recommend a method of attack. The size and importance of the target may be indicated by a request for the fire of additional bat-

teries or battalions. To be of maximum value, the report should be transmitted promptly, and the designation should be accurate.

334. TARGET LOCATION. Target locations may be pointed out on the ground; designated by template or grid coordinates; designated by reference to a known point (such as a check point or a target previously fired upon), or by azimuth and range from a known point or observation post; marked on maps or photos, or traced on overlays which match such maps or photos. The reported location is normally that of the center point. For a barrage, the width and direction of barrage must also be designated.

335. OBSERVED AND UNOBSERVED FIRES.

a. When fire can be observed, it is adjusted on the target. (Fire for destruction *must* be observed.) Normally the adjustment is conducted by the observer who reports a target. Accurate initial data will produce early fire for effect by speeding the adjustment.

b. Possible loss of surprise due to adjustment may be avoided if accurate target designation and precise data permit surveillance. Fire for effect is used initially; the observer reports the error or effectiveness of the early fire. The corrections determined for one concentration may be applied to subsequent concentrations.

c. When fires cannot be observed, transfers based on registration should be used. Metro data are used when registration is impossible. When unobserved fires are delivered, it may be necessary to increase the area covered (par. 347).

d. Because of the resulting economy of time and ammunition, and the increase in effectiveness, field artillery always seeks to register. It may be necessary to register with a base piece while other pieces are firing on another mission. Since a single piece firing for registration can be located easily by sound ranging, a registration position may be used and the piece moved following registration. If instrument direction is recorded after registration, the recorded direction may be used subsequently to determine a new deflection correction, or further to refine one corrected by metro. To determine this correction, only the observer at the battery is needed.

e. In the absence of anything better, the correction determined by registration of one battalion may be used by other battalions equipped with the same weapon provided that:

(1) The battalions are connected by survey.

(2) The battalions are not too widely separated laterally or in depth.

(3) The relative calibrations of the battalions are known.

(4) The same ammunition lot is used by all battalions.

336. FORM OF FIRES. Field artillery fires are classified regarding form as concentrations and barrages.

a. Concentration. A concentration is a volume of fire placed on an area within a limited time. The term is applied regardless of the tactical purpose of the fire or the nature of the tactical operation.

b. Barrages. A barrage is a special type of prearranged fire placed on a line or on successive lines. Barrages are fired close in front of our own front lines. (Antipersonnel mine fields can be used to supplement artillery barrages.)

(1) STANDING BARRAGE. A standing barrage is fired on a fixed line.

(2) NORMAL BARRAGE. A normal barrage is a standing barrage placed on a critical area which cannot be covered effectively by the weapons of the supported troops. A battery has only one normal barrage. The normal barrage is usually fired on signal.

(3) EMERGENCY BARRAGE. An emergency barrage is a standing barrage employed to cover gaps between normal barrages or to reinforce the normal barrage of another unit. A battery may have any number of emergency barrages. Such barrages are usually fired on call rather than on signal.

(4) ROLLING BARRAGE. A rolling barrage is artillery fire delivered on successive lines, advancing according to a prearranged schedule. Rolling barrages are employed to support an attack when the locations of hostile dispositions are obscure, or to orient and guide the attacking troops.

(5) BOX BARRAGE. A box barrage is a special type of standing barrage inclosing an area on two or more sides. It is employed to isolate a portion of the hostile position.

(6) WIDTH OF BARRAGE. The rate of fire (par. 348b) and the effective width of burst (par. 18c (2)) limit the width of the barrage which may be effectively covered by a battery. Paragraph 313 shows the width of barrages that should not be exceeded.

337. PREARRANGEMENT.

a. General. All supporting fires, the possible need of which can be foreseen, are prearranged. This means that the location of these fires has been fixed; and although it does not necessarily mean that firing data have been computed in advance, this is desirable for increased accuracy and to expedite the mission. Some of these fires will be delivered on call or on signal only; others will be scheduled, to be fired at a specified time or upon the occurrence of a specific event in the action.

b. Grouping of fires.

(1) GROUPS. To facilitate the tactical handling of prearranged fires, it is desirable to arrange them into "groups of fires," "series," or "schedules." A group of fires consists of two or more concentrations covering a tactical locality which is too large to be covered by a single concentration. The concentrations within the group of fires may be fired consecutively or concurrently, depending upon the scheme of maneuver; the number of concentrations; the number of artillery battalions available; and the size of the concentrations, that is, whether they are battery or battalion concentrations. Groups of fires may be indicated by a letter symbol, a combination of letter symbols, or by a code name.

(2) SERIES. A series consists of a number of groups of fires or concentrations planned to support a maneuver phase. The series has two purposes: first, to facilitate the operation of fire-direction centers by indicating fires that are likely to be delivered during a maneuver phase; and second, to facilitate placing fires in tactical localities too large to be covered by a single group of fires. An example of the latter would be defensive fires to protect an objective when taken, or fires to cover in depth and width a large locality under enemy attack.

(3) SCHEDULES. A schedule consists of a number of concentrations, groups of fires, or series fired in a definite sequence according to a time schedule. The time of starting the schedule may be on call. For identification purposes, schedules may be referred to by a code name, such as "Schedule, Wolf", or other designation.

c. Reference points. A further aid in expediting either prearranged fires or observed fires is the use of reference points. These are selected terrain features of sufficient prominence to be readily identified by observers. Reference points should be crossroads, road junctions, stream crossings, the sides of bare hills, or prominent landmarks such as buildings and small clumps of trees. Numbers should be assigned these points and the coordinates furnished those concerned with the adjustment of fire. They are used for indexing the terrain for the rapid designation of points on which fire is to be placed. It may be desirable further to index the terrain by assigning letters to large terrain features.

338. PREPARATION OF DATA. The fact that a well trained battalion fire-direction center can compute corrected data for a target and transmit it to the batteries as fast as they can set it off on the pieces should not preclude the necessary preparation of data for targets that can be anticipated. Because of the fact that under battle conditions several targets may require almost simultaneous attack, communication may become confused, or fire direction personnel may be considerably

DIVISION (Group; Corps)

ASSIGNMENT OF PREARRANGED FIRES

GROUP	CONCENTRATION NO.	BATTALION TO FIRE	TIME		COORDINATES	ALTITUDE	SIZE		METHOD OF ATTACK	AMMUNITION	REMARKS
			FROM	TO			WIDTH	DEPTH			
DAA	701	664th	on	call	51.622–95.100	433	300	300	½ c apart	48	Fuze quick 2 RGM
	702	763d	on	call	51.478–95.281	437	200	200	Center range	72	Fuze quick 3 RGM
	703	764th	on	call	51.718–95.395	433	200	200	Center range	72	Fuze quick 3 RGM
J	41	764th	on	call	52.692–95.150	420	200	200	Center range	72	Time fire Maximum rate
	615	664th	on	call	52.900–95.184	417	300	200	Center range	48	Time fire Maximum rate
	415	763d	on	call	53.124–95.160	418	200	200	Center range	72	Time fire Maximum rate
W	68	764th	on	call	54.839–95.665	393	200	200	Center range	72	Time fire 3 RGM
	422	763d	on	call	54.904–95.439	397	200	200	Center range	72	Time fire 3 RGM
	625	664th	on	call	55.063–95.570	393	300	200	Center range	48	Time fire 2 RGM

Figure 152. Tabular method of assigning prearranged fires.

EXPLANATION OF FIRE PLAN

Concentration No. This number should be assigned by division or corps artillery from their own block of numbers.

Battalion. This may apply to battalion, group, brigade, or division. One sheet for each. (See Note 1.)

Time. Include here the limitations on time of firing. If it is an *on call* mission it should be so stated. Times may be given with respect to H-hour.

Coordinates. Give the coordinates of the center of the concentration. (For assignment of area targets see Note 2.)

Altitude. The altitude of the center of the concentration in yards.

Size. Give the size in yards. Concentrations 701, 615, and 625 are appropriate for 155-mm battalions. Concentrations 705, 703, 41, etc. are appropriate for 105-mm battalions. (See Note 2.)

Method of attack. Examples are *center range, 1 c apart,* etc. The method of attack by a range spread is applicable for attacking targets in depth; the increase in range spread increases the size of the area covered in the direction of fire only. If the area to be covered is greater than that covered by a standard battalion concentration firing at center range or with range spread, the method of attack must be decided upon by the lower unit commander who breaks it down into separate standard size battalion (or battery) concentrations. (See Note 2.) (See section II, this chapter.)

Ammunition. The amount of ammunition to be expended on the mission.

Remarks. Any additional information pertinent to firing the mission, such as rate and type of fire, and any other unit firing on the target at the same time.

NOTES

1. Fire plan sheets are made in duplicate, one for the unit concerned and the other for file.

2. The assignment of prearranged fires may be made by *overlay* and graphical time schedule. This method is particularly applicable when area targets are being assigned. The use of an overlay will eliminate the coordinates, altitude, and size columns from the fire plan sheet.

3. A graphical time schedule is useful as a work sheet in planning fires, and as a quick reference for commanders to determine which units are firing.

COUNTERPREPARATION—SERIES FOX
(Based on attack localized in sector of 1st Infantry)

Bns to Fire / Targets Assigned	Schedule of Fires: H	+2	+4	+6	+8	+10	+12	+14	+16	+18	+20	+22	+24	+26	+28	+30	+32	+34	+36	+38	+40	+42	+44	+46
764th FA Bn 1, 65, 68, 81, 83, 87, 94, 97, 103, 105, 107, 110, 121, 707, 710	710/72		83/72	87/72		121/48	103/48		97/48	94/72		105/36	107/72		110/72	68/72		65/72	1/48		81/72	707/72		
763d FA Bn 3, 421, 422, 426, 427, 428, 429, 430, 431, 432, 433, 434, 436, 708, 709	709/72		427/72	428/72		436/48	431/48		430/48	429/72		432/36	433/72		434/72	422/48		421/72	3/48		426/72	708/72		
664th FA Bn 624, 625, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 640, 706, 711	711/36		630/36	631/36		640/24	635/36		634/18	633/36		636/18	637/36		638/36	625/36		624/36	632/36		629/36	706/36		
762d FA Bn 3, 68, 90, 97, 107, 110, 122, 312, 327, 328, 421, 432, 635, 708, 710	708/72		90/72	312/72		122/48	635/48		97/48	327/72		432/36	107/60		110/72	68/72		421/72	3/48		328/72	710/72		

NOTES

1. The graphical schedule is valuable to show which battalions are available for fire on targets of opportunity. Figures above horizontal lines indicate concentration numbers; figures below lines indicate ammunition allotted. Fire will be distributed over the period of time covered by the line. The heading shows time in 2-minute intervals with respect to H-hour.

2. Size of concentrations must be indicated on the overlay or by prearrangement.

3. A similar graphical schedule is used by battalions in designating battery concentrations.

Figure 153. Schedule of fires.

reduced, it is highly desirable to compute the more critical firing data in advance. This is particularly true for scheduled fire missions requiring refinements in adjustment of sheaf or echelonment in depth, or missions of such importance that they are to be fired on signal as well as on call. Normal barrages are examples of this latter type. The data is generally prepared by battalion fire-direction centers, although batteries should also be prepared to perform this operation.

339. CENTRALIZATION OF CONTROL.

a. Higher artillery.

(1) Division or corps artillery commanders coordinate the fires of their subordinate artillery units, and allocate reinforcing artillery fires to further the plan of the force commanders. Figures 152, 153, and 154 illustrate methods of assigning prearranged fires by division or corps.

(2) The group, division artillery, or corps artillery commander centralizes control when communication makes it possible. With centralized control, battalions may engage targets in their zones of fire within limitations imposed by the group, division artillery, or corps artillery commander. A battalion which has been given a direct support mission fires outside of the sector or zone of the supported unit only after obtaining clearance from the division artillery commander; general support battalions are massed on order of the commander of the group, division artillery, or corps artillery; a battalion which has a reinforcing mission answers all calls for fire from the reinforced unit when answering such calls will not interfere with the primary mission.

b. Battalion. The battalion commander centralizes control when communication makes it possible. With centralized control, batteries may engage targets in their zones of fire within limitations imposed by the battalion commander. Observers within the battalion may be required to report all targets to the battalion. When a single battery is to fire on a target, the observer may be directed to give sensings or commands either to the fire-direction center or direct to the battery. When more than one battery is to fire on a target, the observer normally gives sensings or commands to the fire-direction center, from which commands are sent to the batteries.

c. Battery. At times (for example, in rapidly moving situations or if communication is lacking), control of fire has to be decentralized to the batteries. In this situation, the observers report fire missions and other information direct to the battery.

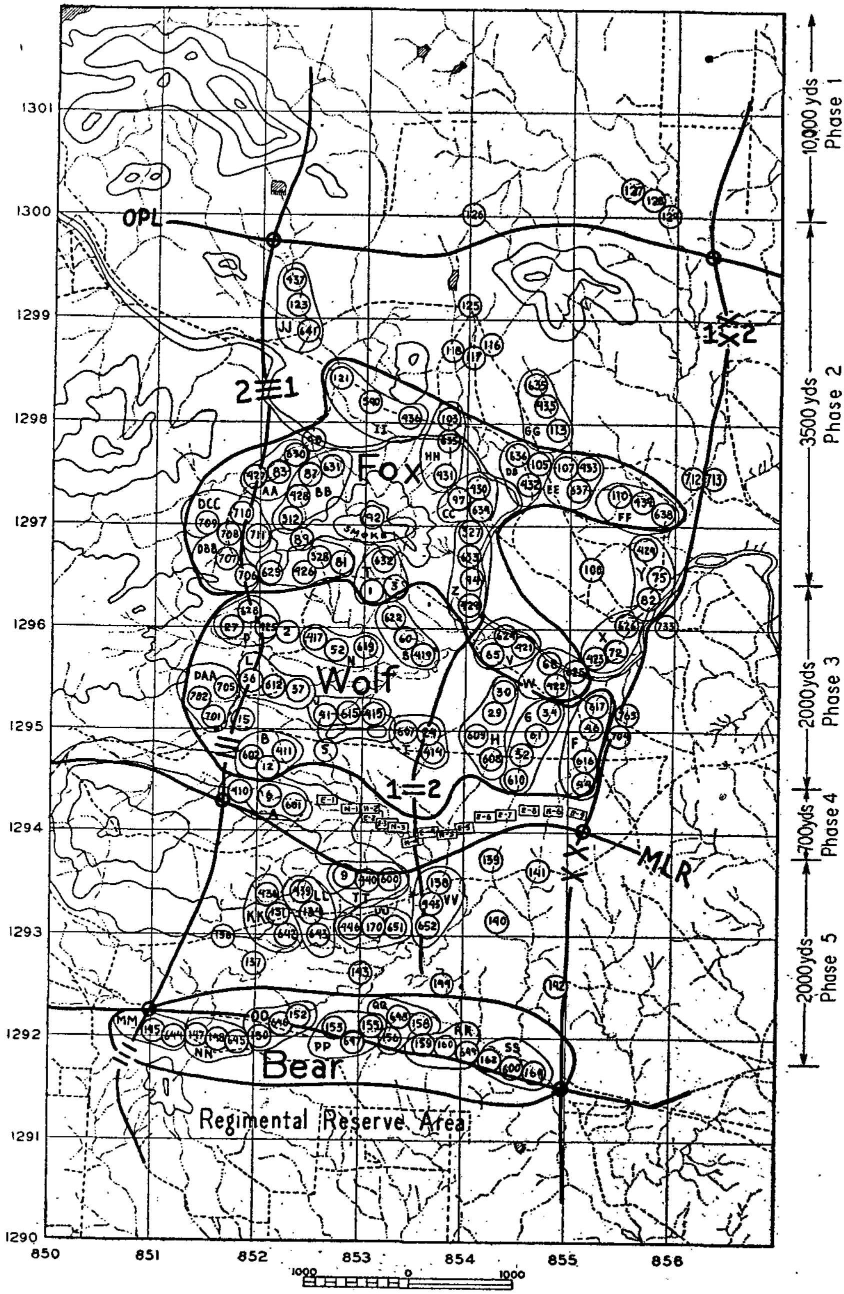


Figure 154. This figure illustrates a division artillery fire plan issued in overlay form as an annex to the division artillery order, which in turn is an annex to the division field order.

Figure 154 illustrates a division artillery fire plan issued in overlay form as an annex to the division artillery order, which in turn is an annex to the division field order. The graphical schedule of fires (fig. 153) may be shown on the overlay or as a separate annex.

PHASE 1—Long range fires; harassing and interdiction fires beyond outpost line.

PHASE 2—The counterpreparation—series Fox. Fires designed to break up the attack before it can be launched.

PHASE 3—Fires in depth and width to stop the attack before it reaches the battle position. (Prearranged groups and observed targets of opportunity.)

PHASE 4—Final defensive fires. Barrages and defensive concentrations on call to prevent penetrations of our main battle position.

PHASE 5—Fires to limit penetration and to support counterattack.

ASSIGNMENT OF CONCENTRATION NUMBERS	
UNIT	BLOCK
764th FA Bn	1–199
762d FA Bn	200–399
763d FA Bn	400–599
664th FA Bn	600–699
Div Arty	700–850

ASSIGNMENT OF BARRAGES		
UNIT	NORMAL	EMERGENCY
764th FA Bn	N–1 N–2 N–4	E–5 E–4 E–1
664th FA Bn	N–3 N–5 N–6	E–9 E–2 E–3
763d FA Bn		E–6 E–7 E–8

340. ASSOCIATED ACTIVITIES. Effective centralized control requires planning and execution of the following associated activities:

Organization for combat; assignment of missions and zones of fire.

Survey; maintenance of suitable charts.

Communication.

Intelligence relative to targets, to include actual location of known targets, estimated location of targets, and anticipated location of potential targets.

Ammunition supply.

Observation: ground, air, sound and flash.

Regular broadcast of metro messages; registration.

Liaison and joint planning with supported troops.

Construction of a fire capabilities chart. (See FM 6–100 and FM 6–101.)

Operation of a fire-direction center.

341. AMMUNITION LOTS. Small numbers of rounds from varied ammunition lots are used for battery bracket missions. When a battalion has a relatively large number of rounds of one lot, that lot is divided among batteries and is used for registration, transfers, and massed fires. A minimum number of lots is sought for each battalion.

Section II. ATTACK OF TARGETS

342. METHOD. When the location of a target and the time of attack are known, the commander must, within the time available, consider the following points pertinent to the method of attack:

a. Nature of the target (type, mobility, cover, importance).

b. Results desired.

c. Registration and survey control available.

d. Size of the target.

e. Allowance for errors (location and correction).

f. Rate of fire.

g. Amount of ammunition available.

h. Unit or units to give desired coverage.

i. Conformity of the fire to scheme of maneuver of the supported unit.

j. Technique of attack.

343. NATURE OF THE TARGET. The nature of the target to be attacked determines the projectile, fuze, and caliber selected (chap. 3, PART ONE). It also determines the size of bracket sought, the type of adjustment, and speed of attack. Study of enemy methods and equipment will assist materially in the selection of the best methods.

344. RESULTS DESIRED. The method of attacking a target is influenced by the results desired from the fire. In general these results are of three types which by their description furnish a guide for method of attack.

a. Destruction. Fire concentrated on an object which is to be damaged physically to such an extent that it is rendered useless.

b. Neutralization. Fire of great intensity on personnel, with the object of causing severe losses, preventing movement or action, causing limited destruction of materiel, and, in general, destroying the combat efficiency of the enemy.

c. Harassing fire. Fire of less intensity than neutralization, designed to inflict losses, or, by the threat of losses, to disturb the rest of the enemy troops, to curtail movement, and in general to lower morale.

345. REGISTRATION AND SURVEY CONTROL. The lack of ample survey control and registration influences the method of attacking targets by limiting effective transfers or the use of metro data. In this situation, targets cannot be attacked unless observation is possible. Harassing fires only are possible.

346. SIZE. The size of a target may be determined by the actual area covered by the target or by the area in which the target is known to be. This information is obtained from observers' reports, photo interpretation, utilization of all other intelligence agencies, and experience in similar situations.

347. ALLOWANCES FOR ERRORS. When fire can be adjusted on a target, the actual size of the target or area is accepted, but where unobserved fire must be placed on a target, other factors must be considered. In general these considerations are:

a. Errors of basic data. There are errors of location of the piece and the target, both vertically and horizontally, of plotting, and of measurement. Since gunnery methods reduce all but errors in target location, this may be considered the controlling factor. If the expected error in target location is known (based on evaluation of the agency which furnished it), an area of sufficient size to enclose the target probably can be determined. If fire of the desired intensity is placed on all of the area, the proper amount of fire will be placed on the target.

b. Errors of correction. These errors are the result of differences between the corrections actually applied and the effect of existing conditions. They vary with the accuracy of registration, distance from base or check point, the time elapsing between registration and firing on the target, the weather conditions in the interim, the accuracy of the metro message and determination of the *VE,* as well as other factors. For this reason, fire may have to be placed on an area even larger than the target inclosing area, to be sure of cover by fire.

c. Areas. Based on the considerations above, the area appropriate for the target is increased as shown in the table below. (As a general guide, the following amounts can be considered appropriate):

Type of Fire	*Width (each side)*	*Range (over and short)*
Observed fire	None	None
Transfer of fire (*K* or *VE*)	0–5 mils	0 to ½ fork
Metro data	5–10 mils	½ to 1 fork

d. Longer ranges. It is evident from the discussion above that, for the longer ranges, the area to be covered may become so large (and

so great an ammunition expenditure would be necessary) as to preclude any unobserved fire other than harassing or interdiction fires.

348. RATE OF FIRE.

a. General. The greatest possible demoralization and effect result when surprise fire is delivered with maximum density, all units firing with allowance for time of flight to cause all projectiles to strike simultaneously (*time on target* method). Because of limits to the rates of fire, (see b below), density is best secured by massing the fires of several batteries, and in certain cases, battalions. Offsetting the advantage of great initial effect, however, is the fact that coverage of an area by many weapons may give a beaten zone larger than the target, and is therefore wasteful of ammunition. Furthermore, effective massed fires cannot be sustained without extravagant ammunition expediture. These factors may dictate the use of small units even when more batteries and battalions are available.

b. Table showing permissible rates of fire.

Rounds per Piece (Volleys per Battery)

MATERIEL	1ST ½ MIN	1ST 4 MIN	1ST 10 MIN	PROLONGED FIRE PER HR
75-mm howitzer	8	24	48	150
105-mm howitzer	4	16	30	100
4.5-inch gun	3	12	22	50
155-mm howitzer	2	8	16	40
155-mm gun	2	8	14	40
8-inch howitzer	—	6	10	30
8-inch gun	—	3	6	20
240-mm howitzer		3	6	20

Note: For the rates of fire above, it is assumed that pieces have been rested or cooled from previous firing. Each column includes the total of the preceding column. If the rate of fire of one of the first three columns is to be used in several missions, time between missions must be sufficient for cooling the pieces.

Lower charges have a lesser heating effect than the higher charges, thus increasing the permissible rate of fire.

The table above is to be used as a guide only; however, the rates of fire shown should not be exceeded at maximum charge.

349. AMOUNT OF AMMUNITION.

a. The amount of ammunition available and allotted is the first consideration in the attack of targets. The amount available will vary from no ammunition allotted (to preserve secrecy regarding the amount of artillery present or because of a shortage of ammunition supply) to no restrictions on firing and an ample supply of ammunition available.

In the situation more frequently met, there will be an allotment of so many rounds per gun per day. Such an allotment will not be exceeded except by authority of the headquarters establishing the allotment. For example, 20 rounds per gun per day for 105-mm, 4.5-inch, and 155-mm calibers; 10 rounds per gun per day for 8-inch and 240-mm calibers. Additional rounds are expended only in case of an enemy attack. Division artillery commanders are allotted an additional 6 rounds per gun per day, 105-mm, 4.5-inch, and 155-mm calibers.

b. When quantity of ammunition allotted is small, approximately 10 to 20 rounds per 105-mm howitzer per day, missions should be limited to those which can be observed and which immediately affect our own troops and operations. When quantities allotted are larger, 20 to 100 rounds per howitzer per day, missions fired should include the above plus those which may affect planned or future operations, as well as those which will require some massing of artillery without adjustment. Quantities from 100 to 300 rounds per howitzer per day have been allotted for a wide variety of purposes, from an offensive action of a local nature to a general action on a broad front. Quantities of ammunition indicated above will vary somewhat in different theatres and will, of course, be smaller for larger calibers.

c. The ammunition shown in figures 155 and 156 show the number of rounds required for initial neutralization. With more cover, difficult terrain, or a well disciplined enemy, the amount of ammunition necessary will materially increase.

350. SELECTION OF UNIT TO GIVE COVERAGE.

a. General. If the unit to fire cannot confine its fire to an area as small as the target area plus allowances for errors in location and corrections, ammunition will be wasted. On the other hand, if the unit can cover only a very small part of the target area at a time, surprise is lost in sweeping the target area, and the rate of fire for the area as a whole may be insufficient to secure effect. When the dispersion pattern is large, the direction of fire should be such that the maximum effect is obtained from the beaten zone of dispersion. The caliber, and type of shell for the most effective fire must be considered. The first step in selecting the unit for a mission is to insure that it is of a proper size and caliber to cover the target area quickly and economically.

b. Battery. Figure 155 shows the area covered by a battery firing at a single range, as well as the amount of ammunition to cover it. The size of the area to be covered governs the method of firing. By using shifting fire, batteries may cover wider areas; by using zone fire, or fire at successive ranges, they may cover deeper areas than those specified in figure 155.

AREA AND AMMUNITION	CALIBER						REMARKS
	75-mm	105-mm; 4.5-inch	155-mm	8-inch howitzer	8-inch gun	240-mm	
Size of Area Covered*	50 × 100	75 × 100	100 × 100	150 × 150	120 × 150	130 × 150	Firing with sheaf converged on a point.
Amount of Ammunition to Cover	20	12	12	16	12	12	
Size of Area Covered*	120 × 100	150 × 100	250 × 100	380 × 150	230 × 130	250 × 150	Firing with open sheaf.
Amount of Ammunition to Cover	48	24	32	36	24	20	

* Size of area covered: First figure is *width*, and second figure is *depth*.

Figure 155. Area covered and ammunition necessary for one battery firing at center range to neutralize temporarily troops without cover.

METHOD OF ATTACK	AREA AND AMMUNITION	CALIBER				REMARKS
		75-mm	105-mm; 4.5-inch	155-mm	8-inch howitzer	
Center Range	Size of Area Covered*	100 × 150	150 × 150	160 × 150	200 × 150	Firing with sheaf converged on a point target.
	Amount of Ammunition to Cover	48	36	24	24	
Center Range	Size of Area Covered*	150 × 200	200 × 200	300 × 200	400 × 200	Firing with open sheaf.
	Amount of Ammunition to Cover	96	60	60	60	
½ c Apart	Size of Area Covered*	150 × 250	200 × 250	300 × 250	400 × 250	Firing with open sheaf.
	Amount of Ammunition to Cover	108	72	72	72	
1 c Apart	Size of Area Covered*	150 × 300	200 × 350	300 × 350	400 × 350	Firing with open sheaf.
	Amount of Ammunition to Cover	144	108	108	108	

* Size of area covered: First figure is *width*, and second figure is *depth*.

Figure 156. Area covered and ammunition necessary for one battalion to neutralize temporarily troops without cover; data computed for a single point.

c. Battalion. When more than one battery is available, the fire of all batteries may be superimposed.

In superimposing this fire, the batteries may fire at a single range or with a range spread between batteries. The range spread between batteries depends on the size of the area to be covered. Figure 156 shows areas covered by the fire of battalions of various caliber as well as the ammunition necessary to cover these areas.

d. Large area targets.

(1) ONE BATTALION. When the area covered by the target is too large to be covered by a single concentration, it is attacked in parts. If a battery is available for each part, and its fire is deemed sufficiently dense when zone fire is used, the entire area may be attacked at one time. Otherwise, the parts are attacked successively by the battalion. Large areas should be covered only when an important target is spread out over the area.

(2) ADDITIONAL BATTALIONS. The fires of more than one battalion on a target increase the density and surprise effect of the fire, and the size of the area covered. Areas covered by more than one battalion firing at a single point in an area (data for all battalions computed for the same point with open sheaf; corrections for calibration and for echelonment in depth *not* applied) are approximately as follows:

Two battalions, 105-mm howitzer (or 4.5-inch gun):
250×300 yards.

Two battalions, 155-mm (gun or howitzer):
400×300 yards.

Three battalions or more (one of them medium or heavy artillery):
400×400 yards.

If battalions apply standing corrections and fire within transfer limits, the above figures reduce to:

Two battalions, 105-mm howitzer (or 4.5-inch gun):
200×250 yards.

Two battalions, 155-mm (gun or howitzer):
350×250 yards.

Three battalions or more (one of them medium or heavy artillery):
350×300 yards.

If the area is too large to be covered by a single concentration, it is attacked in parts. If a battalion is available for each part, and its fire is deemed sufficiently dense, the entire area may be covered at one time. Otherwise, the parts are attacked successively by all battalions.

351. CONSIDERATIONS AFFECTING UNITS TO FIRE.

a. Most targets are of such size as to allow a wide variety of choice in the number of batteries or battalions to be used against them. Al-

though certain limitations are indicated on large targets, the decision whether to have many units firing a few volleys, or a few units firing many volleys, is often a critical one.

b. The factors affecting the selection of units to fire on a target vary with each specific situation. Listed below are those factors which influence this decision.

(1) AVAILABILITY OF ARTILLERY. When the amount of artillery present is small, a greater number of targets per artillery unit must be attacked than is the case when greater amounts of artillery are present.

(2) SIZE OF AREA TO BE COVERED. The use of several battalions on a target almost always covers a larger area than does a single battalion, no matter how carefully corrections are applied. To attack a small target with the fire of a division artillery, for example, will increase density of fire on the target, but in a smaller ratio than the increase in ammunition expenditure.

(3) CERTAINTY OF EFFECT. The increased coverage of larger units may make it desirable to mass more artillery against certain targets, not only to gain increased effect on the center, but to insure some effect over the entire area.

(4) CALIBER AND TYPE OF UNITS. The projectiles of large calibers are more effective for certain destruction missions. High velocity weapons are desired for maximum penetration in attack of fortifications. The accuracy of the weapon at the range fired, as indicated by the probable error in the firing tables, will limit the use of certain weapons. All of the above factors must be considered in selection of the caliber and type unit to be used. The unsuitability of certain calibers for a specific mission may dictate the need for greater ammunition expenditure from a smaller number of more suitable units.

(5) SURPRISE. Against certain targets, short bursts from many pieces are preferable to sustained fire from a few pieces. To secure surprise, the technique of attack must be varied constantly.

(6) ACCURACY OF TARGET LOCATION. Certain targets are so indefinite as to size and location as to justify fire of large units to insure coverage.

(7) CRITICAL TARGETS. The emergency nature of certain targets (such as enemy counterattack formations) may justify the use of all available artillery fire, without regard to economy of ammunition.

(8) RANGE. Coverage at long ranges is less dense.

(9) DISPERSION. This may require that a unit fire along the long axis of the target to obtain the maximum effect from dispersion at long range.

(10) MAINTENANCE OF NEUTRALIZATION, INTERDICTION, AND HARASSING FIRE. This may require the use of small units for a long period of time so that the bulk of the artillery available is free for other missions.

(11) REGISTRATION. Registration reduces the number of units necessary to cover a target, with a corresponding reduction in ammunition expenditure.

(12) VULNERABILITY OF TARGETS. Some targets, such as truck parks, should be attacked with massed fire to insure immediate effect and to release the artillery for other missions.

(13) SIZE OF TARGETS.

(14) AMMUNITION SUPPLY AVAILABLE.

352. DISTRIBUTION OF FIRE.

a. Large targets offer a wide choice in methods of distributing the fire of units selected to fire on them. While time may be saved in some cases by designating the center of a large area for all units to fire upon, fire of more uniform density usually is secured by assigning individual target coordinates to each unit to fire.

b. Great care must be exercised in firing on area targets close to supported troops. Battalions able to fire within transfer limits or at short ranges should be chosen to cover the near edge of the area.

c. Normally a battalion should not fire with a range spread greater than 1 *c*, since a greater spread will not give uniform coverage of the target. The probable error at the range to the target should be considered in the choice of range spread to be used.

353. FIRE SUPPORT OF A UNIT. To permit the most effective artillery fire in support of a unit, artillery fire plans should be prepared to conform to the scheme of maneuver of the supported unit commander. (See par. 337 on prearranged fires.) Once action is started, the artillery maneuvers its fire to continue the support in accordance with reports of liaison officers and forward observers with these units.

354. TECHNIQUE OF ATTACK. The technique of attack is determined by a careful analysis of the capabilities of the weapons and ammunition available, the terrain of the target area, and the most effective method of attacking the target. High angle fire may be necessary from defiladed positions or may be required to reach into deep ravines or irregular terrain. Time fire may be used most effectively against personnel within the limitations of the fuze. Direct fire with mobile, high velocity guns is desirable for direct laying destruction missions. Heavy caliber howitzers are desired for greater accuracy and blast action in destruction missions at long range.

CHAPTER 2
FIRE-DIRECTION CENTERS

355. FIRE-DIRECTION CENTER. The fire-direction center consists of personnel, equipment, and communication facilities necessary to assist the commander in the execution of the mission of fire support. In the execution of fire direction orders, personnel of the fire-direction center prepare firing data for both observed and unobserved fires, and conduct unobserved fires.

356. BATTALION.

a. General.

(1) Using the fire-direction center, the battalion commander (or his representative) can direct all types of fire with any or all of the batteries. He assigns prearranged fires, to include preparations and barrages, to conform to the plans of maneuver of the supported troops. He is able to prohibit or authorize fire on targets reported by observers, and has facilities for prompt execution of fire missions ordered by higher headquarters. The personnel and equipment are grouped as conveniently as possible consistent with safety.

(2) The efficiency and speed in execution of fire missions in the fire-direction center derives from division of labor, standing operating procedure, and mechanical devices (graphical firing table). The combination of these makes a team of the fire-direction center, in which all operations must be performed in a specified sequence, and every possible means must be used to eliminate errors.

b. S-2. The battalion S-2 has three functions pertaining to fire direction:

(1) To procure and distribute maps and photographs.

(2) To locate and report targets.

(3) On request of the S–3, to be prepared to use his knowledge of the target, enemy habits, and the situation, to advise on a method of attack.

(4) When necessary, to clear fire missions close to own troops and in front of adjacent units.

c. S-3.

(1) In addition to his other duties, the S–3 is the gunnery officer of the battalion. He plans and supervises the activities of the fire-

direction center. When a target is reported, he notes its location relative to the front lines, zones of fire, and check points. Acting in accordance with the general policy of the commander and based on these considerations, and with a view to the importance of the target and the amount of ammunition available, the S–3 decides whether the mission will or will not be fired. If the target is to be taken under fire, he specifies appropriate parts of the following:

(*a*) Basis for corrections (par. 313).
(*b*) Use of special corrections (par. 100).
(*c*) Projectile (par. 18).
(*d*) Charge (par. 82).
(*e*) Fuze (par. 18).
(*f*) Concentration number.
(*g*) Batteries to fire (pars. 342–354).
(*h*) Adjusting battery.
(*i*) Number of volleys (pars. 342–354).
(*j*) Range spread or zone (pars. 342–354).
(*k*) Time of opening fire.

If the fire is to be observed, items (*e*) to (*k*) are transmitted to the observer reporting the target. The concentration number is assigned from the block of numbers pertaining to the battalion. If an adjustment is to be conducted on a check point or base point for the determination of corrections, or if the fires of other batteries are to be superimposed on the fire based on the adjustment of one battery, most effective fire will result if the adjustment is made with the battery most centrally located. Time of opening fire is dependent on the nature of the target and the type of effect sought. The desirability of initial surprise is a dominant factor.

(2) It is essential that all S–3s realize the importance of active supervision at all times. It is their responsibility that fire be delivered with speed and *without errors.*

d. HCO. The horizontal control operator executes the following duties under the supervision of the S–3:

(1) FIRING CHART. He prepares the surveyed firing chart if this has not already been done by survey personnel, and constructs the observed fire chart when one is used (pars. 360–363).

(2) BASE LINE EXTENSIONS (figs. 157 and 158). HCO plots base line extensions. A base line extension is the prolongation of a line passing through the base piece and the base point, and materialized on the chart so as to intersect one of the scales for measurement of horizontal angles on the range-deflection fan. The entire base line is drawn for the center battery, as this line is used as the origin for sensings in

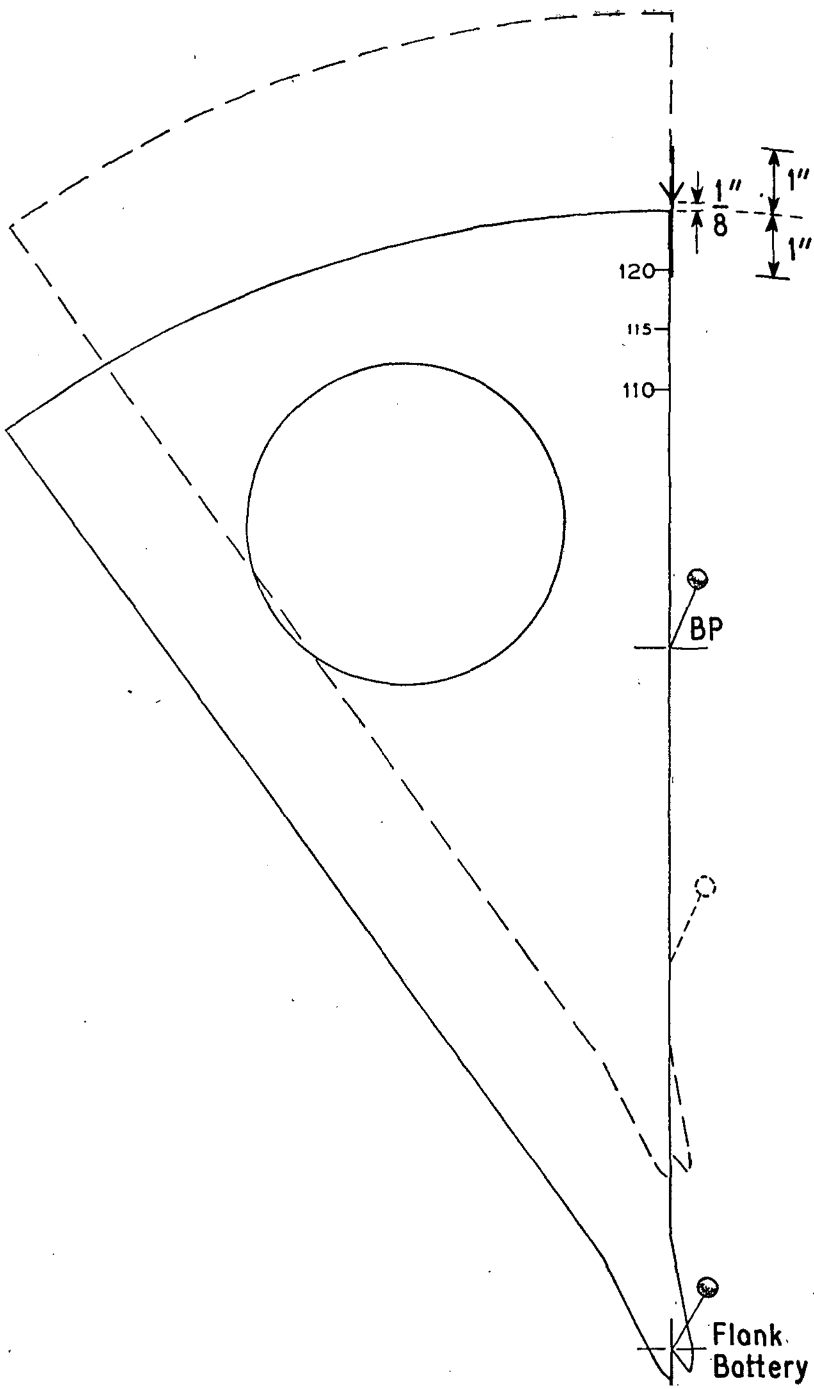


Figure 157. Method of plotting base line extension.

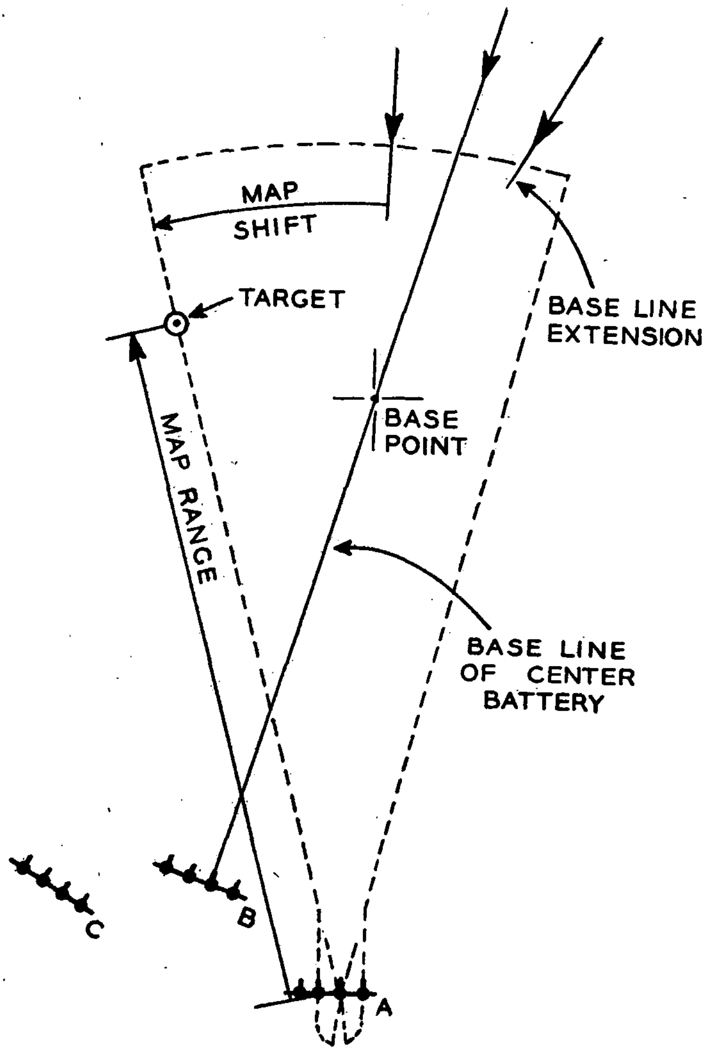
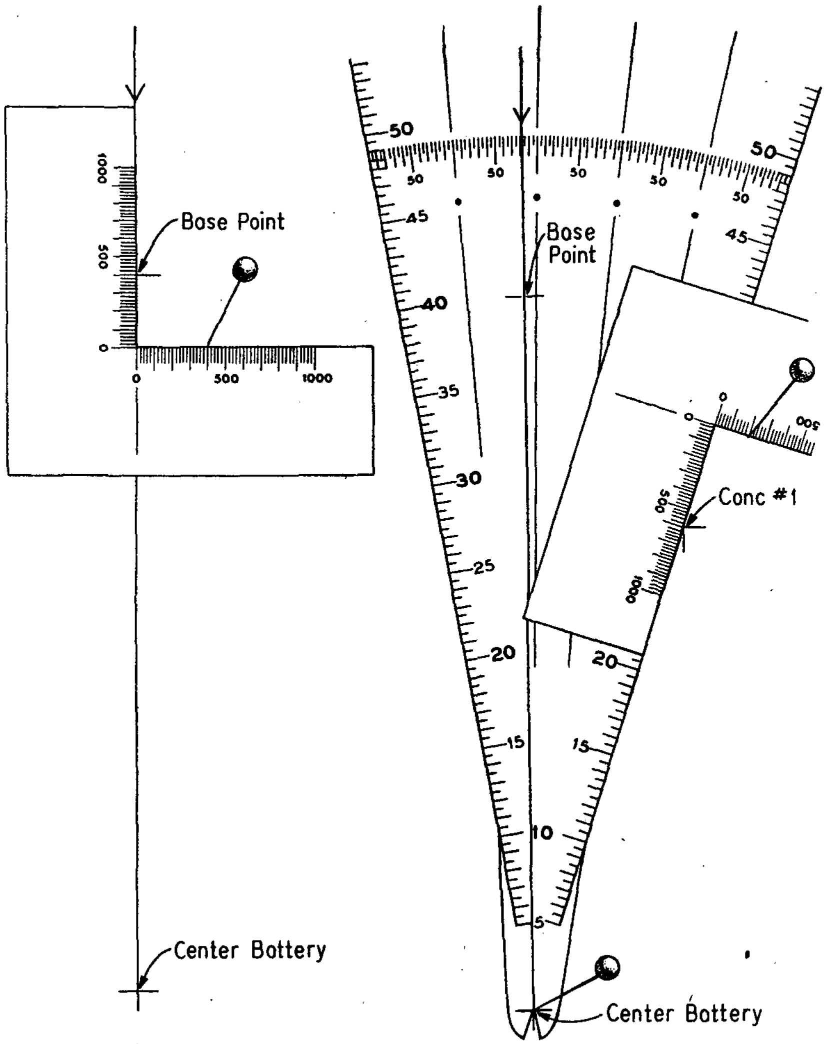


Figure 158. Base line extensions of three batteries.

relation to the base point. For the flank batteries, the extension is merely drawn 1 inch on either side of the angular scale. For all three batteries, an inverted arrow is placed on the base line extension 1/8 inch beyond the angular scale. These arrows as well as the battery locations on the chart are marked according to the appropriate color scheme (Battery A, red; Battery B, white or black; Battery C, blue). This rigid procedure is used to facilitate measurements for direction, and to obviate to a great extent the possibilities of error (par. 188b and fig. 62).



a　　　　　　　　　　b

Base Point is 400 L, 400+　　　　Conc #1 is 200 L, 600−

Figure 159. Use of the coordinate scale for plotting targets.

(3) PLOTTING TARGETS. HCO plots targets reported to the fire-direction center by coordinates (pars. 181-190), by the operator of the AS base (par. 253), by the computers as data for replot following an adjustment (par. 188c), or by an observer as so many yards right (left) and over (short) of the base point or other designated point on the firing chart. For this latter method, he uses the coordinate scale, orienting it so that one edge of the scale is along the line of the

center battery and the designated point (fig. 159). The HCO does *not* write down the coordinates or other designation, but starts to plot *without delay.* If he forgets part of the necessary information, the computer will repeat it on request (see duties of computer below).

(4) DEFLECTION CORRECTION SCALE. When corrections have been obtained, HCO receives deflection corrections from the appropriate computer and places them in scale form on his range-deflection fan (par. 327 and fig. 151). When points of registration are numerous, additional scales may be necessary.

(5) DETERMINING AND ANNOUNCING DATA. When a target is to be fired on, HCO determines and announces data in the following order:

(*a*) *Correction all batteries.* In a mission involving an adjustment, this is the deflection correction at the initial range for the adjusting battery; in a surprise fire mission, this is the deflection correction at range of the center battery. Where consderable echelonment in range exists between batteries, separate corrections may be necessary. In high angle fire, the correction for the appropriate charge for each battery is announced.

(*b*) *Battery designation, map range, map shift;* for example: "Baker, 4720, Right 108." For an adjustment mission the order of batteries to receive this data is: adjusting battery, right nonadjusting battery, left nonadjusting battery; for a surprise fire mission: center battery, right battery, left battery. This stereotype procedure enables a fire mission to be speeded through the fire-direction center.

(6) DATA ON FIRING CHART. HCO keeps all concentrations, and the location of friendly front lines and observers plotted on his chart.

(7) VCO DATA. The HCO and VCO charts are the same. The HCO must be able to perform the duties of the VCO.

e. VCO.

(1) The vertical control operator prepares and maintains a chart identical to that of the HCO. The VCO must be able to perform the duties of the HCO. For a fire mission, the VCO determines the site for each battery (including the additional $20/R$ in time fire, and the complementary angle of site when necessary). These computations may be performed by arithmetic, but they are greatly speeded by the use of a Mannheim or military slide rule. He performs his computations in the same battery order as the HCO's announcement of data, and announces the sites on request of the respective computers (par. 308). He makes a semipermanent record of sites similar to the following:

BTRY	BP	CK PT NO. 1	CONC NO. 57	CONC NO. 72
A	+5	−1	−3	+7
B	+6	0	−2	+9
C	+5	0	−2	+6

(2) Upon completion of an adjustment, the VCO determines the altitude of the target, using the final site setting of the adjusting battery. For time fire, he subtracts 20 yards from that altitude. When a firing chart with considerable altitude control (battle map) is used, if there is considerable variation between the adjusted altitude and that read off the chart for the replotted location, the average of these altitudes is taken and a new site determined. This site is then announced to the computer; for example, "Site for replot, Baker +10." The computer subtracts this site from the adjusted quadrant elevation, and determines a new range for replot from the remainder.

(3) Measures which will assist the VCO to determine sites accurately include:

(*a*) Study of the topography of the target area from observation post.

(*b*) Determination of spot altitudes by survey.

(*c*) Stereoscopic examination of pairs of photos.

(*d*) Accentuation of drainage and ridge lines on the firing chart.

(*e*) Study of oblique photos.

(*f*) Study of the record of adjusted sites for concentrations on which time fire was adjusted. (A time correction must have been determined and used in the adjustment.)

f. Computers. There is a computer for each battery. The general duties of the computers are to record information and data; compute data for firing, corrections, and plotting of targets; and to announce fire commands, corrections, and data for plot of targets. A computer's record is shown in figure 160.

(1) RECORDING. Computers record the following:

(*a*) Fire missions reported to the fire-direction center.

(*b*) S-3's order.

(*c*) HCO and VCO data.

(*d*) Computations and commands.

(*e*) Ammunition expended and on hand.

(2) COMPUTING. Computers must know and understand the battalion standing operating procedure on methods of handling fire missions, and must be prepared to make the following computations (for a reference on detailed description, operation, and uses of the graphical firing tables, see TM 9–524 for the 12-inch tables, and TM 9–526 for the 16-inch tables):

(*a*) Conversion of S-3 fire order and HCO and VCO data into fire commands.

(*b*) Conversion of observers' sensings into fire commands (see par. 140).

(*c*) Determination of corrections (not only from *will adjust* missions, but also corrections that are determined from registrations and metro messages).

(*d*) Data for the replot of a target at the completion of adjustment.

(*e*) Determination of special corrections when ordered.

(3) ANNOUNCING. Computers announce the following:

(*a*) Fire commands to the battery.

(*b*) Corrections as determined in (2) (*c*) above to the members of the fire-direction center.

(*c*) Data for the replot (or plot) of targets as determined by firing (or from an observer). Computers announce data for the replot of a target in the following order: battery adjusting, base deflection shift, range, site, fuze (or time), and concentration number. For example: "Data for replot, Baker: BDL 253; range 3250; Si +25; FD; concentration 54."

The computer is the final medium through which all the work of the fire-direction center must pass to the battery with the least possible delay. For example, at the completion of the S-3 order, BATTERY ADJUST, SHELL HE, CHARGE 5 should be sent to the battery immediately (fig. 160). After receiving the HCO data, the computer should set 5010 on his GFT, read the corresponding fuze setting, and send TIME 18.0. Then he combines the deflection correction, map shift, and shift to center sheaf, and sends BDL 82. He determines the deflection difference, and commands ON NO. 2 CLOSE 4. At this time (*not* before), he turns to the VCO and requests SITE BAKER, and, on receiving the site, sends it to the battery, followed by CENTER, 1 ROUND, ELEVATION 300. This practice of having the computer determine and send commands piecemeal enables the battery to fire within a very few seconds after it has received the elevation. A computer should *never* determine all of his data and then send the entire series of commands to the battery (except in preparation of a data sheet for prearranged fires).

Battery B	COMPUTER'S RECORD	Conc No 9 (c)
Btry Front 160 yds	Time Mission Completed 1536	Date 1 Jan 45

Fire Mission: BP is 400 R, 20 Below, 400 −, 2 MG's, Will adjust. (b)	B Adjust Sh HE (c) Ch 5 (c)
S-3 Order: T.F., Bn, B, 3 ½ c apart, When Ready. (c)	Fz or Ti 18.0 (a) BD L 82 Sheaf at
Defl Corr L 11 (d) Range 5010 (d) Map Shift L 74 (d) Shift to Center Sheaf R 3	DD On #2 CL 4 (e) Si 306 (f) MF C 1 EL 300 (a)

SENSINGS	SUBSEQUENT COMMANDS
200 L, G, 400 +	R40, U10, Ti 16.4, 270
100 R RR	L22, 270
100 −	Ti 16.8, 277
10A, 50+, FFE	U2, Ti 16.6, B3, 273
	Corr R18, U12, −27 (g)
Mission accomplished, MG's neutralized	Data for Replot: Baker, BDL 56, Range 4660, Si + 18, T.F., Conc 9. (h)

Ammunition Expended:	
20 rds Sh M1 " Fuze M54	Close $\frac{60}{3R} = 4$ (e) Replot: L 74 + R18 = L 56 (h) Si + 6 + 12 = + 18 (h)

EXPLANATORY NOTES

(*a*) GFT setting = charge 5, range 4820, El 285, Ti 17.2.
(*b*) Observer's initial sensing and target designation.
(*c*) From S–3; the range spread applies to the nonadjusting batteries.
(*d*) From HCO.
(*e*) Uniform battery front: close by deflection difference to form an open sheaf.
(*f*) From VCO.
(*g*) Announced to other computers.
(*h*) Announced to HCO and VCO. Shift and site derived by applying corrections (*g*) to initial map shift and site; range read from GFT.

Figure 160. Suggested form for computer's record.

357. PLOTTING TARGETS; CHART LOCATION DETERMINED BY FIRING.

a. General. *Will adjust* missions differ from *fire for effect* missions in the following respects:

(1) Target is plotted initially based on the observer's estimate.

(2) The computer of the adjusting battery must compute and announce the *corrections* determined from the adjustment.

(3) The computer of the adjusting battery must compute and announce the data for the replot of the target.

(4) When necessary, the VCO checks the site for the replot location of the target (par. 356e (2)).

(5) The HCO and VCO plot the accurate location of the target from the data announced by the adjusting computer.

b. Necessity for plotting adjusted location.

(1) The adjusted location of the target serves as a future reference for firing.

(2) If the fire of a battalion is to be placed on a target by the adjustment of one battery, the corrections determined by the adjusting battery are applied to the initial chart data of the nonadjusting batteries. If the S-3 decides that the application of these corrections to the chart data of the nonadjusting batteries will not place their fire on the target, he orders the target to be replotted and new chart data determined for these nonadjusting batteries. The necessity for determining new chart data is dependent on the relative positions of the batteries, the amount of the corrections, and the type of target.

(*a*) If the batteries are spread over a wide area, it may be necessary to replot and determine new chart data for the nonadjusting batteries for all such fires.

(*b*) If the batteries are close together and the replotted location of the target varies from the initial plotted location by more than 500 yards, it may be necessary to determine new chart data for the nonadjusting batteries.

(*c*) When the target is mobile and rapid fire for effect is the prime consideration, the corrections determined by the adjusting battery are applied to the nonadjusting batteries in order to obtain quick fire on the target. When the target is fixed and not apt to move, the replot method should be used in order to obtain the most accurate fire on the target.

(3) When additional artillery fire is to be placed on the target, the accurate chart location of the target must be predetermined. (See par. 358.)

c. Method of marking concentrations on a firing chart. The plotted location of a target on a firing chart is marked as shown in figure 161. The concentration number is marked in the upper right hand quarter, the altitude (surveyed or adjusted) in the lower left hand quarter. For targets on which surveillance was available or which were replotted following an adjustment, the fuze used is placed in the lower right hand quarter. The distinction between a surveyed or adjusted location is further emphasized by plotting a surveyed target in black and a replotted target in red. The upper left hand corner may be used to show the charge if desired; for example in high angle fire.

	18
363	Q

Figure 161. Method of marking concentrations on a firing chart.

358. GROUP, DIVISION ARTILLERY, OR CORPS ARTILLERY. (See FM 6–100.) When targets have been reported, the fire-direction center of group, division artillery, or corps artillery is concerned primarily with: the decision to fire; the assignment of battalions to fire; the allotment of ammunition; the designation of time of firing; and the transmission of the directions for fire to the battalions. (See figs. 152 and 153.) A fire capabilities chart is maintained. The following are included in the directions for fire:

Coordinates of target (including altitude if known).

Nature of target.

Amount of ammunition to be used (or rate of fire) with type if necessary.

Time of opening fire; duration of fire.

CHAPTER 3
THE OBSERVED FIRE CHART

359. GENERAL. When fires must be massed before the completion of a chart based on survey, an observed fire chart is used. When the battalion maintains an observed fire chart, each battery also maintains its own observed fire chart. Each battery registers on the battalion base point with the projectile, charge, and fuze specified. After completion of the registration each battery reports its adjusted compass, base angle (if orienting line has been established), adjusted time (if time fuze is available), site (if it can be determined), and adjusted quadrant elevation.

360. CONSTRUCTION.

a. Direction. The observed fire chart may be constructed on a grid sheet, piece of plain paper, map, or photomap. On a grid sheet, select a grid intersection as the location of the base point; on a piece of plain paper, select any point; on a map or photomap, use the actual location of the base point. The point selected on a grid sheet or piece of plain paper must be so located that the target area and position area can both be plotted on the sheet. Through the base point, draw a ray in the direction of each battery.

(1) On a map, photomap, or grid sheet, the rays are drawn on the back azimuths of the adjusted compasses.

(2) On a piece of plain paper, a straight line is drawn for the center battery, and the rays to the flank batteries are drawn by laying off at the base point the angles representing the differences in adjusted compasses of the respective batteries. Orientation can be indicated by an arrow drawn to represent *Y*-north.

(3) To improve direction, a common orienting line may be established before or during registration. After registration, each battery reports its adjusted base angle as well as its adjusted compass (the latter for orientation of the chart and as a check against large errors). The rays to the flank batteries are plotted by differences in base angles, so that errors of the magnetic needle will not affect the relative location of batteries.

b. Range. The following methods are used to plot the ranges to the batteries:

(1) TIME SHELL UNAVAILABLE, SITES TO BASE POINT UNKNOWN. The ranges correspond to the adjusted quadrant elevations.

Example: The batteries of a 105-mm howitzer battalion have registered on the base point, using shell HE, charge 3, fuze quick. All batteries have a common orienting line. Adjusted data are:

Battery	*Adjusted Compass*	*Adjusted Base Angle*	*Adjusted Quadrant Elevation*
A	1055	1696	330
B	1143	1610	353
C	1287	1463	339

An intersection of two grid lines is selected as the location of the base point. Through the base point is drawn the ray to Battery B, the center battery, the *Y*-azimuth of which is 4343 (back azimuth of the adjusted compass). The battery is located on its ray or base line by laying off the range of 3640 from the base point (fig. 162). The flank batteries are plotted by placing the base of the range-deflection fan at the base point and by laying off angles to the right and left of the center battery base line equal to the difference between the base angle of the battery to be plotted and the base angle of the center battery. A pin point is placed along the side of the fan at the appriate range (3460 for Battery A and 3530 for Battery C) (figs. 163 and 164).

(2) TIME SHELL UNAVAILABLE, SITES TO BASE POINT KNOWN. The observed fire chart is more accurate if the sites to the base point can be determined either from a small scale map or by

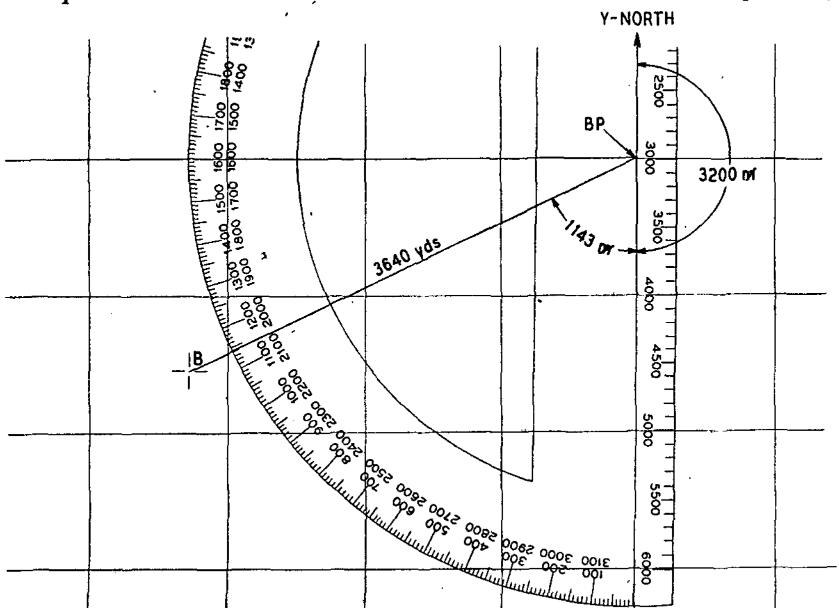


Figure 162. Plotting center battery on the observed fire chart.

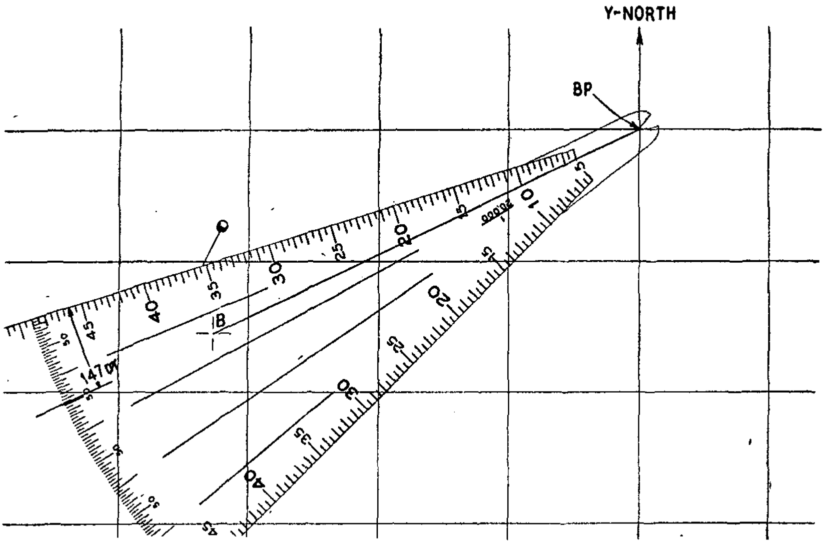


Figure 163. Plotting a flank battery on the observed fire chart.

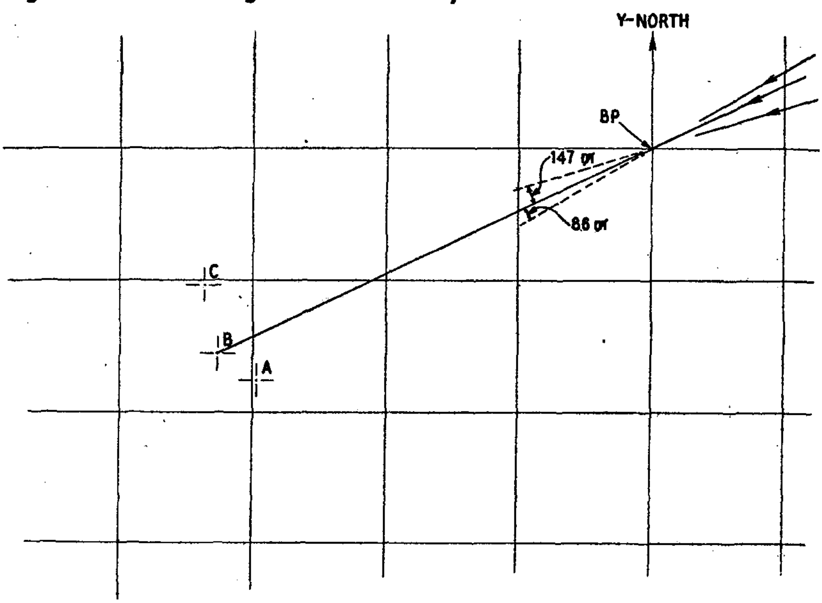


Figure 164. Completed observed fire chart.

computation with instruments. Batteries are plotted as in (1) above except that plotted ranges correspond to adjusted elevations instead of to quadrant elevations. The base point is given an arbitrary altitude and the relative altitudes of batteries are determined by the mil relation.

Example: The batteries of a 75-mm howitzer battalion have registered on the base point, using shell HE, charge 3, fuze quick. All batteries have a common orienting line. Adjusted data are:

Battery	*Adjusted Compass*	*Adjusted Base Angle*	*Site**	*Adjusted Elevation*
A	3844	1761	296	385
B	3729	1878	304	392
C	3782	1824	311	420

*Complementary site not included.

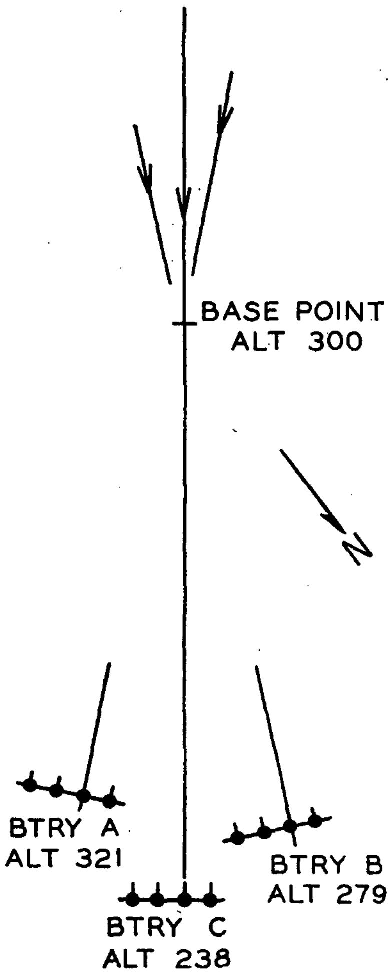


Figure 165. Construction of observed fire chart (plain paper).

In this case a piece of plain paper is to be used for the construction of the observed fire chart. A point is selected for the location of the base point. A straight line is drawn through the base point to represent the base line of Battery C (the center battery). A pin point is then placed on this line to represent the battery at a range of 5560 yards from the base point. The flank batteries are plotted by the method given in the last example with the appropriate angles and ranges (Battery B 54 mils to the right of C, range from base point 5330; Battery A 117 mils to the left of C, range from base point 5270). An arbitrary altitude of 300 yards is assigned to the base point. The altitude of Battery A is 321 yards, (300 + (4 × 5.3)); the altitude of Battery C is 238 yards, (300 − (11 × 5.6)). (Fig. 165.)

(3) TIME SHELL AVAILABLE, SITES TO BASE POINT UNKNOWN. Each battery makes a time registration on the base point. The procedure thereafter is similar to that in (1) above, except that the ranges plotted are the firing table values corresponding to the respective adjusted times.

The firing table values for elevations corresponding to the respective adjusted times are considered the adjusted elevations; sites are determined by subtracting each adjusted elevation from the corresponding adjusted quadrant elevation. Relative altitudes are determined from these derived sites and tabular ranges, using the mil relation. A large time correction will cause sites thus determined to be considerably in error. When this error occurs, batteries will mass effectively only when echelonment of batteries in range is not greater than 500 yards or when targets are near base point range.

Example: The batteries of a 105-mm howitzer battalion have registered on the base point, using shell HE, charge 5, fuze M54. Adjusted data include:

Battery	*Adjusted Time*	*Adjusted Quadrant Elevation*
A	17.0	308
B	17.6	315
C	16.3	295

The altitude of the base point is taken arbitrarily as 500 yards. Data for plotting batteries on an observed fire chart:

Battery	*Range*	*Elevation*	*Site*	*Altitude*
A	5060	294	314	429 yards
B	5220	306	309	453 yards
C	4880	281	314	431 yards

(4) TIME SHELL AVAILABLE, SITE TO BASE POINT DETERMINED. The method given in (3) above is improved if the site to the base point for one battery can be determined from a small scale map, by computation with instruments, or by firing (see par. 318). The ranges plotted are the firing table values corresponding to the respective adjusted times. The GFT setting is determined as follows: Subtract site from adjusted quadrant elevation for the battery whose site has been determined, place the hairline over adjusted time, and draw a gage line at adjusted elevation. To determine sites of the other batteries, set the hairline over the adjusted time for the battery in question, and read the elevation under the elevation gage line; subtract this elevation from the adjusted quadrant elevation to obtain site. Altitudes are determined from these derived sites and tabular ranges by use of the mil relation. An observed fire chart set up in this manner is preferable to one set up by the methods given in (1) and (3) above.

Example: The batteries of a 105-mm howitzer battalion have registered on the base point with shell HE, charge 5, fuze M54. Adjusted data include:

Battery	Adjusted Time	Site	Adjusted Quadrant Elevation
A	17.0	Not determined	308
B	17.6	Not determined	315
C	16.3	305	295

GFT setting is range 4880, elevation 290, adjusted time 16.3. This setting is appropriate for all missions fired using this chart. Altitude of base point arbitrarily is assumed to be 500 yards. Data for plotting batteries on observed fire chart:

Battery	*Range*	*Elevation*	*Site*	*Altitude*
A	5060	304	304	480 yards
B	5220	316	299	505 yards
C	4880	290	305	475 yards

c. Alternate method. In some situations, time and ammunition can be saved by eliminating the registration of two batteries and substituting a position area survey. Usually this procedure sacrifices accuracy, since the survey is to a known scale, whereas the range plot includes the *K* (and time *K*).

361. USE OF OBSERVED FIRE CHART. When the observed fire chart is used for firing, the procedure is the same as with a firing chart based on survey, with the following exceptions:

a. Since the observer has no means for determining coordinates, target designation is usually made with reference to a target previously fired on (fig. 166).

b. Site is assumed to be zero when a chart constructed as in paragraph 360b (1) is used.

c. No corrections are applied to data from charts constructed as in paragraph 360b (1), (2), and (3).

d. When targets are attacked with time fire, range for replot is read from the GFT, with the adjusted time gage line over the adjusted time for the target in question. Altitudes for replot are determined by computation based on altitude of adjusted battery, adjusted site minus $20/R$, and range for replot.

362. USE OF TARGET AREA BASE WITH OBSERVED FIRE CHART. Good results often are obtained by using a target area base for rapid location of targets and delivery of surprise fires from an observed fire chart. Since the length of the target area base is determined by survey, whereas the scale of the chart includes *K*'s, the procedure gives

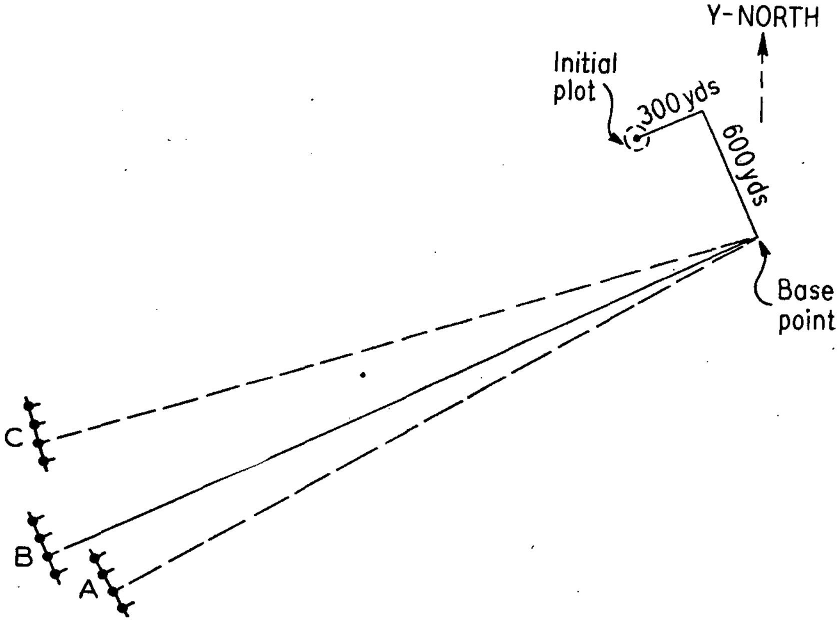


Figure 166. Use of the observed fire chart.

uncertain results at ranges materially different from base point ranges. The *Y*-azimuth and distance from the controlling end of the base to the base point are measured; a ray is plotted through the base point on the observed fire chart with the corresponding back azimuth; the location of the controlling end of the base is determined by plotting the computed distance along this ray. The base point is used as the reference point. The procedure thereafter is as given in paragraphs 249-256.

363. TRANSFER FROM OBSERVED FIRE CHART TO A CHART BASED ON SURVEY.

a. The firing chart based on survey is put into use as soon as it is available. Until all concentrations are transferred to the firing chart based on survey, the observed fire chart is retained for reference in case observers use such concentrations for known points in designating targets. To avoid the necessity of using two charts, the transfer is made as soon as possible. (*Note:* A copy of the firing chart may be made for use in planning fires and computing prearranged data.)

b. The corrections for use with the new firing chart are based on: range measured on the firing chart; altitudes determined by survey; adjusted time determined by registration; adjusted elevation determined from adjusted quadrant elevation minus site determined by

survey; and deflection correction zero at base point range. It should be noted that the pieces have been given direction by registration.

c. Data for replot of targets located by adjustment are determined from the records of the recorder of the adjusting battery, using the corrections established for the new firing chart. Targets located by target area base, and adjusted upon, are plotted on the firing chart by the same method.

d. Each battery maintains its own firing chart and keeps it up to date. The battalion promptly transmits any additional data to the batteries. This procedure enables fire direction to be decentralized at any time.

364. OBSERVED FIRE CHART FOR MORE THAN ONE BATTALION.

a. The common control required for massing quickly the fires of more than one battalion is secured by the uniform declination of instruments, the designation of a common check point for all battalions and the assignment of coordinates and altitude thereto, and the registration by one battery of each battalion on the common check point. After registering on the common check point, the registering battery reports the adjusted data.

b. To construct the observed fire chart, each battalion plots a ray from the check point on the back azimuth of the adjusted compass reported by the adjusting battery. The distance and the altitude of the battery are determined by one of the methods given in paragraph 360b (the last method is preferable). The method used for determining the lengths of the rays should be the same in all battalions. The difference in adjusted compasses to check point and base point (or the base deflection shift to the check point) is determined, and this angle is laid off from the ray, in the appropriate direction, vertex at the adjusting battery; a ray is drawn and the distance from the battery to the base point is marked thereon. The remainder of the observed fire chart is constructed as set forth in paragraph 360.

c. It is important that relative altitudes of division artillery check point and battalion position areas be known if several widespread battalions are to mass accurately.

d. As an example, the battalion has prepared an observed fire chart, using the method outlined in paragraph 360b (4). The division artillery commander selects a check point visible to all battalions, and assigns it arbitrary coordinates (10.0–80.0) and the arbitrary altitude, 320 yards.

The battalion registers the base piece of its center battery on the division artillery check point and plots the back azimuth ray (from

division artillery check point to Battery B (fig. 167)), using the method given in paragraph 360b (4). Battery B has now made two registrations: one on the base point, and one on the division artillery check point. The difference between the two adjusted compasses (or the adjusted deflection) gives the angle 1 (fig. 167). The distance from Battery B to the battalion base point is now plotted on the new chart as one side of the angle 1 (fig. 167). Batteries A and C may now be plotted in their correct relative positions (see broken lines). The vertical control which the battalions have already established is co-

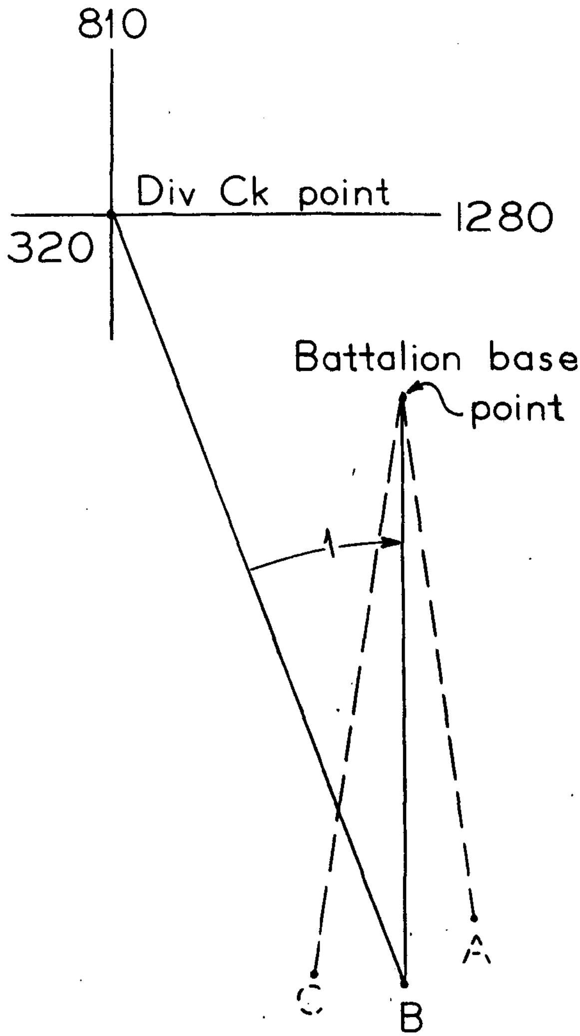


Figure 167. Observed fire chart built by registration on division artillery check point.

ordinated with the altitude assigned the division check point. The chart is now ready for operation. When the fire of one battery has been adjusted on a target, the coördinates and altitude of the replot can be furnished the other battalions that are to fire on the same target.

CHAPTER 4
EXAMPLES OF MASSED FIRES

365. EXAMPLE 1. Corps has assigned to a battalion of 155-mm guns M1 the mission of neutralizing a hostile battery, the location of which has been restituted from a vertical photo to the firing chart (a battle map in this example). Observation is impossible, *VE* has been determined, but further registration is impossible at this time. It is decided to fire three volleys, surprise fire, from all batteries. The S–3 announces: CORRECTIONS FROM METRO CHECK POINT NO. 3, FUZE QUICK, CONCENTRATION 207, BATTALION THREE VOLLEYS, 1 *C* APART, AT MY COMMAND.

Upon announcement of METRO CHECK POINT NO. 3, each computer sets his GFT with range 14,420, elevation 442 (normal charge), which is the setting previously determined for that point.

HCO announces:

Correction all batteries R 3

B	15,220,	L 481
A	14,860,	L 488
C	14,780,	L 506

VCO announces (upon request of computers):

Site B +2
A +7
C +5

In each battery, No. 2 is the base piece. Battery fronts are A 320, B 160, C 210, and regularly spaced. The shift to center sheaf (33/*R*, or 2 mils) is included in base deflection shift. Computers send the following commands to batteries:

B	*A*	*C*
B ADJ	B ADJ	B ADJ
SH HE	SH HE	SH HE
N CH	N CH	N CH
FQ	FQ	FQ
BDL 476	BDL 483	BDL 501
ON NO. 2 OP 1	ON NO. 2 CL 3	———
B 3 RDS AMC	B 3 RDS AMC	B 3 RDS AMC
Q 498	Q 485	Q 463

When all computers signify "Battery is ready," S–3 commands FIRE; the computers immediately relay the command to the batteries.

366. EXAMPLE 2. Two 105-mm howitzer battalions are grouped for direct support of an infantry regiment. The group commander (commander of the organic battalion) has issued instructions that all targets will be reported to group headquarters. Firing chart—photomap. A forward observer reports *LQ54, machine guns pinning down infantry, additional fire, will adjust.* It is decided to fire 6 volleys using both battalions. The reinforcing battalion is warned: MACHINE GUNS; FIRE SIX VOLLEYS; COORDINATES IN A FEW MINUTES. S-3 of the organic battalion orders: TRANSFER FROM BASE POINT, RICOCHET FIRE, CONCENTRATION 82, BATTALION, CHARLIE, SIX VOLLEYS, CENTER RANGE, WHEN READY. HCO plots the coordinates on the photomap firing chart, and announces:

Correction all batteries R 4

C	6330,	R 166 (adjusting battery first)
A	5920,	R 161
B	5980,	R 183

VCO announces (upon request of computers):

Site C —3
A +5
B +2

In each battery, No. 2 is the base piece. Base deflection has been recorded with No. 2 on the base piece. Battery fronts are reported irregular in width and depth: A 110, B 250, C 180 (see par. 99). GFT setting, charge 5: Rn 5170, El 287. The shift to center sheaf (17/*R*, or 2 mils) is included in base deflection shift.

Computers send the following commands to batteries:

C	*A*	*B*
B ADJ	B ADJ	B ADJ
SH HE	SH HE	SH HE
CH 5	CH 5	CH 5
FD	FD	FD
BDR 172	BDR 167	BDR 189
SHEAF AT 6500	SHEAF AT 6000	SHEAF AT 6000
SITE 297	SITE 305	SITE 302
C 1 RD	B 6 RDS	B 6 RDS
EL 377	DNL EL 343	DNL EL 348

During the adjustment, the deflection is changed Right 24, and elevation is increased 9 mils. The last sensing includes *mine action.* Computer C commands FQ, B 6 RDS, 386, and announces "Corrections: FQ, R 24, plus 9; data for replot, Charlie, BDR 190, range 6430, Si —3, FQ, conc 82." Computer B commands FQ, R 24, 357. Computer A commands FQ, R 24, 352. HCO and VCO plot BDR 190, range 6430

on the firing chart, and HCO measures the coordinates of the target; these coordinates, the altitude, and the instructions TIME FIRE are transmitted to the reinforcing battalion. In the fire-direction center of the reinforcing battalion, data are determined from the firing chart. The procedure thereafter is similar to that in example 1.

367. EXAMPLE 3. 105-mm armored battalion (six piece batteries). Registration has been made with charge 4; the adjusted time 12.0 and elevation 230 were obtained on the base point, range 3060. Firing chart—grid sheet.

A forward observer sees a dug-in antitank gun. The crew is exposed. He believes personnel will take cover in undercut fox holes on the fall of the first rounds. He desires maximum initial antipersonnel effect. He is certain of the accuracy of his target location. He reports: *(2.51–7.62). Antitank gun and personnel. Converged sheaf; special corrections; battalion; single volley; time fire; fire for effect.*

The battalion is firing to maintain neutralization of an area. It is decided to withdraw Battery B (center battery) to fire on the antitank gun. S-3 orders: CONVERGED SHEAF, SPECIAL CORRECTIONS, TIME FIRE, CONCENTRATION 141, BAKER, 1 VOLLEY, AT MY COMMAND.

HCO announces:
Correction, Baker, L 9
Baker 3340, R 512

VCO announces (upon request):
Site, Baker, plus 12 (includes $20/R$)

The battery executive's report for position area plot was:
From No. 3:
No. 1; 70 R, 55 in front
No. 2; 45 R, 85 in front
No. 4; 80 L, 20 in rear
No. 5; 115 L, 25 in rear
No. 6; 140 L, 15 in front

Base deflection was recorded with parallel sheaf on the base point. Measurements and convergence are with respect to the base piece, No. 3. No shift to center sheaf required.

Computer B commands:
B ADJ
SPECIAL CORRECTIONS
CH 4
TIME 13.2
NO. 1, MINUS .3; NO. 2, MINUS .4; NO. 4, PLUS .2; NO. 5. PLUS .3; NO. 6, PLUS .2
BDR 503

NO. 1, L 10; NO. 4, R 9; NO. 5, R 24; NO. 6, R 37 (taken from convergence table for range 3500)

SITE 312; NO. 1 DOWN 8, NO. 2 DOWN 9, NO. 4 UP 4, NO. 5 UP 6, NO. 6 UP 4 (Echelonment corrections and calibration corrections, if known for charge 4, are included in individual sites.)

B 1 RD AMC

256

As soon as the battery reports ready, the S-3 commands FIRE.

The observer reports *30 air, 25 over; at least three casualties; request precision fire; will adjust.*

Fire for destruction is continued with a single piece.

368. EXAMPLE 4. The commander of Battery A of a 75-mm howitzer battalion reports a target to the fire-direction center as follows: "Counterattack, lateral methods, request time fire, request battalion, will adjust." It is decided to fire superimposed zones with Batteries A and B. The battery commander is notified "Time fire, concentration 43, Able and Baker, adjust Able, when ready." The battery commander then sends commands to the fire-direction center: B ADJ, SH HE, CH 3, FR 3800, BDL 130, SITE 310, CR, 3800. Computer A relays the commands to the battery, substituting TIME 13.3 for FR 3800, and EL 245 for 3800. He requests corrections for 3800. HCO announces "Correction all batteries, L 6." Computer A announces "Data for initial plot, Able, BDL 124, range 3800, Si +10, conc 43." HCO and VCO plot these data and determine data for Battery B. Deflection changes made during the adjustment total R 36; changes of site total U 7; fire for effect is started at 3500. Computer A commands EL 222, announces "Corrections: R 36, U 7, minus 23; data for replot, Able, BDL 88, range 3500, Si +17, time, conc 43"; and, when appropriate, commands EL 230, 214, 218, 226 (with appropriate times). Computer B commands R 36, U 7, and gives the successive times and elevations to fire Battery B through the zone.

369. EXAMPLE 5. The commander of Battery B of a 105-mm howitzer battalion, acting under authority to fire on targets in the zone of the battalion, commenced a lateral bracket adjustment on what appeared to be an infantry platoon. He then realized that a hostile regimental reserve was forming for a counterattack, and instructed the executive: "Two companies forming for counterattack, request battalion." The executive directs the telephone operator on the simplexed circuit to repeat the request to the fire-direction center and to read the initial commands from the recorder's sheet. Data for initial plot are determined as in example 4.

The battery commander informs the executive when his adjustment is complete (specifying center range if necessary). The executive reports the adjusted data to fire-direction center.

370. EXAMPLE 6. A forward observer of a 155-mm howitzer M1 battalion under corps control reports *Base point is 600 left, 50 above, 800 short; tank battalion park; all additional fire; will adjust.* HCO plots the target on the firing chart (a grid sheet). It is decided to fire six rounds with the battalion and to request all possible additional fire from corps artillery. The request to corps artillery takes the form: "671st FA Bn now adjusting on tank battalion; approximate coordinates (68.11—94.87); request all possible additional fire." Approximate coordinates and the fire capabilities chart make it possible for corps artillery to determine which battalions can fire on the target. Corps artillery warns the 672d and 673d Field Artillery Battalions: "Tank battalion, coordinates in a few minutes, fire at once, maximum rate for 5 minutes, keep this line open." Corps artillery informs the 671st, which in turn informs the observer, that two additional battalions will fire at maximum rate for 5 minutes. The batteries of the 671st Field Artillery Battalion are considerably separated laterally and in depth, and poor massing would result with the method used in example 2 if the initial target designation is much in error; for that reason, data for nonadjusting batteries will be determined after a replot of adjusted data. The following illustrates the procedure:

S-3 orders TRANSFER FROM BASE POINT, CHARGE 5, GREEN BAG, FUZE QUICK, CONCENTRATION 146, BATTALION, BAKER, SIX VOLLEYS, CENTER RANGE, WHEN READY.

HCO announces "Correction all batteries L 10, Baker, 6240, R 98."

VCO announces, upon request of computer, "Site Baker —6." (Altitude of base point, 418; altitude of battery, 406.)

Shift to center sheaf (33/6.2) = R 5.

Computer B commands: B ADJ, SH HE, CH 5, GREEN BAG, FQ, BDR 93, SHEAF AT 6500, CENTER, 1 RD, EL 275.

At the conclusion of the adjustment, computer B commands, for example, B 6 RDS, 286. The deflection on No. 2 (the base piece) is now BDR 72. Computer B announces "Data for replot, Baker, BDR 77, range 6420, Si —6, FQ, concentration 146." HCO replots the target, announces the coordinates, and announces for example: "Able, 7180, R 64; Charlie, 6910, R 87."

VCO verifies site of adjusting battery on replot data. Site is within 1 mil. Coordinates and altitude are sent immediately to corps artillery and thence to the other battalions.

VCO announces site, and computers A and C send commands to their batteries to fire six volleys.

The procedure used by the 672d and 673d Field Artillery Battalions is similar to that in example 1 except that "center range" and "when ready" should be specified.

371. EXAMPLE 7. A division artillery observer in a liaison plane discovers a traffic jam in enemy territory. He identifies and marks the pertinent portion of road on his map, writes a brief description of the target, and drops the map and description at division artillery headquarters. The target is divided into suitable parts, and, with the permission of the division commander, all battalions are assigned parts. The message sent to one battalion is: "Traffic jam (84.27–12.61) to (84.53–12.46); fire four volleys per minute from 1442 to 1447, time fire." (*Note:* It is standing operating procedure in this division that the time given for opening fire represents the time that initial volleys are to reach the target.) The air observer is directed to execute surveillance during the attack. The execution of the directions is similar to that in previous examples except in the matter of coverage. The coordinates furnished by division artillery show the limits of the portion of road assigned to the battalion. The battalion divides its portion into battery targets and prepares a *K*-transfer for each. A strip of road running approximately at right angles to the line of fire is attacked with batteries abreast, each firing a single range. A strip of road running along the line of fire is attacked with 100-yard sheafs, range spread between batteries, and (if necessary), zone fire by batteries. A diagonal strip of road is attacked with an appropriate combination of the above, and, if time permits, with application of special corrections to fit the sheaf to the road.

372. EXAMPLE 8. A forward observer of a 105-mm howitzer battalion has discovered a target beyond the steep hill which he occupies. He reports *Base point is 800 left, 30 below, repeat range, company of infantry beyond hill; high angle fire, battalion, will adjust, initial volley at my command.* S-3 announces SHELL HE, HIGH ANGLE FIRE, DISREGARD SITE, FUZE QUICK, CONCENTRATION 87, BATTALION, ADJUST BATTERIES SIMULTANEOUSLY, FIVE VOLLEYS, CENTER RANGE, AT MY COMMAND. The battalion has not registered with high angle fire. A correction for drift is included in the initial commands in order to place rounds in the location designated by the observer.

HCO: A 4140, R 200
B 3810, R 219
C 4380, R 195

All battery fronts are 200 yards.

Computers:

A	*B*	*C*
B ADJ	B ADJ	B ADJ
SH HE	SH HE	SH HE
CH 3	CH 2	CH 3
FQ	FQ	FQ
BDR 148	BDR 174	BDR 148
ON NO. 2 CL 8	ON NO. 2 CL 9	ON NO. 2 CL 8
SI 300	SI 300	SI 300
C 1 RD AMC	C 1 RD AMC	C 1 RD AMC
EL 1128	EL 1066	EL 1087

"Batteries are ready" is reported to the observer when signified by the respective computers.

Observer: *Fire Able.*

Computer A: FIRE. "Able on the way, 41 seconds."

In about 15 seconds, the observer commands *Fire Baker.*

Computer B: FIRE. "Baker on the way, 37 seconds."

About 15 seconds later, the observer commands *Fire Charlie.*

Computer C: FIRE. "Charlie on the way, 40 seconds."

Observer: *Able 200 left, 200 over;*
Baker 300 left, 100 over;
Charlie 200 left, 200 over.

S-3: WHEN READY

Computers:

A	*B*	*C*
CH 2		
R 66	R 81	R 46
C 1 RD	C 1 RD	C 1 RD
1044	1090	1119

As each battery reports "On the way," the report is relayed to the observer.

Observer: *Able 100 over;*
Baker 100 right, 50 over;
Charlie 50 over.

Computers:

A	*B*	*C*
	L 28	
1067	1100	1127

Observer: *Able 30 right, 50 short, fire for effect;*
Baker 25 short, fire for effect;
Charlie 40 left, range correct, fire for effect.

Computers:

A	B	C
L 8		R 10
B 5 RDS	B 5 RDS	B 5 RDS
1056	1095	1127

Battalion to observer: "Battalion firing for effect."

Observer: *Fire effective; activity stopped.*

373. EXAMPLE 9. A 105-mm howitzer battalion is in a position where high angle fire must be used frequently. Firing chart is a grid sheet. Registrations with charges 2, 3, and 4, using high angle fire, have been completed. (Drift is not included in deflection corrections.) A forward observer reports: *Check point 3 is 500 right, 20 above, 500 short; infantry mortars; high angle fire; battalion; will adjust.* S-3 announces TRANSFER FROM CHECK POINT 3, SHELL HE, HIGH ANGLE FIRE, DISREGARD SITE, FUZE QUICK, CONCENTRATION 18, BATTALION, BAKER, FOUR VOLLEYS, CENTER RANGE, WHEN READY. HCO plots the target and announces:

Correction charge 3, R 5

Baker 4420, L 432

In each battery, No. 2 is the base piece; base deflection has been recorded with No. 2 on the base point. Battery fronts are regularly spaced, A and C 130 yards, B 110 yards; GFT settings: charge 2, range 3840, elevation 1076; charge 3, range 4450, elevation 1096; and charge 4, range 5960, elevation 1018. HCO has the range limits of each charge for high angle fire marked on his range-deflection fan.

In high angle fire the adjusted location of the target must be plotted before data for the nonadjusting batteries is determined.

Computer B sends the following commands to his battery, including a shift to center sheaf of R 4 (17/4.4):

B ADJ
SH HE
CH 3
FQ
BDL 472 (L 432 + L 49 + R 5 + R 4)
SITE 300
C 1 RD
EL 1101

Observer's sensings:	Computer B commands:
200 right, repeat range;	L 46, 1101
100 left, 200 over;	R 23, 1137
50 right, 100 short;	L 12, 1122
50 over, fire for effect.	B 4 RDS, 1130

Computer B announces "Data for replot, Baker, BDL 464 (BDL 472 + L 35 – (L 52 + R 5 + R 4)), range 4250, charge 3, concentration 18." HCO replots the target and announces:

Correction charge 3, R 5

A 4650, L 439

C 4350, L 418

Computers A and C send the following commands to their batteries:

A	*C*
B ADJ	B ADJ
SH HE	SH HE
CH 3	CH 3
FQ	FQ
BDL 474 (L 439 + L 44 + R 5 + R 4)	BDL 459 (L 418 + L 50 + R 5 + R 4)
ON NO. 2 CL 2	ON NO. 2 CL 2
SITE 300	SITE 300
B 4 RDS	B 4 RDS
EL 1060	EL 1113

APPENDIX I
SERVICE PRACTICE

Section I. GENERAL

1. PURPOSES OF SERVICE PRACTICE. Service practice is a part of the tactical field exercise training of field artillery units and it should combine all elements of field artillery training: tactical employment, mobility, signal communication, and preparation, execution, and conduct of fire. The preparation, execution, and conduct of fire with service ammunition by field artillery units is the final phase of training for battle.

2. QUALIFICATION OF OFFICERS FOR SERVICE PRACTICE. Field artillery must be able to deliver fire accurately and promptly. All field artillery officers must be highly skilled and disciplined in the techniques for preparing and conducting fire. It is the primary duty of all field artillery commanders to establish and maintain this precept in their units by example and training. Officers must be so trained and disciplined in the techniques of preparation and conduct of fire prior to service practice that the opportunity to demonstrate their skills by firing service ammunition is looked forward to as a privilege and not as an ordeal. The degree of proficiency which affords the field artillery officer satisfaction in a demonstration of his skill at service practice can be established and maintained only by constant practice under simulated combat conditions.

3. BATTERY TRAINING FOR SERVICE PRACTICE. The degree of fire discipline and proficiency in signal communication which is required for service practice is established and maintained by daily training in the gun park and in nonfiring exercises. Accuracy in execution must be the foundation, and this principle must be emphasized from the first day of training. Before a gun or howitzer battery is designated to fire at service practice, it must be established that the unit is qualified to transmit and execute fire commands with accuracy and speed.

4. COMMANDING OFFICER. The commanding officer of a post, camp, or station is responsible for the preparation, maintenance, and assignment of field artillery ranges which are allotted to his command. If required by local conditions, the commanding officer should

prescribe such additional regulations as may be necessary to insure that the safety precautions prescribed in AR 750–10, "Range Regulations for Firing Ammunition for Training and Target Practice," are complied with. A range officer and such other personnel as may be necessary are detailed to assist the commanding officer in the discharge of this duty.

5. OFFICER IN CHARGE OF FIRING. Safety in firing is the responsibility of the officer in charge of firing. The officer in charge of firing is the officer charged with the conduct of any exercise or training which involves the firing of live ammunition. The officer in charge of firing is assisted by the range officer and by a safety officer detailed for duty at each battery position.

6. THE RANGE OFFICER.

a. The range officer is responsible to the commanding officer for the proper preparation and maintenance of the range. The range officer is responsible that the danger areas of the range are cleared of all individuals prior to firing, and that properly instructed range guards are posted so as to cover all normal approaches to the danger areas to prevent trespassing during firing, and that the prescribed warning signals are displayed. During the firing, the range officer is an assistant to the officer in charge of firing.

b. The range officer authenticates the safety card or otherwise assures himself that the safety limits as given to the safety officer are correct and in accordance with regulations.

7. THE SAFETY OFFICER. The safety officer is the representative of the officer in charge of firing at the battery position. Orders issued by the safety officer which prohibit firing are lawful and can be rescinded only by the officer in charge of firing or by the commanding officer. The safety officer will identify the ground limits of the prescribed impact area in which it is safe for projectiles to fall (AR 750–10). He will also determine the minimum range line for the battery position after the pieces have been emplaced. Determination of this line is required when a mask or friendly troops, or both, are between the pieces and the impact area. This line will become the short limit of the impact area when it is at a greater distance than the minimum prescribed by AR 750–10. After the pieces are emplaced, the safety officer will determine for the various powder charges and projectiles the limits of instrument and range settings which must not be exceeded, or below which firing must not take place, if the projectiles are to fall within the impact area. The safety officer will authorize the executive officer to fire only when all safety precautions and pre-

scribed safety regulations have been complied with at the battery position, and when the pieces to fire have been laid with instrument settings and loaded with powder charges and projectiles which will cause the projectiles to fall inside the impact area. The battery executive will not order the firing of any piece until he has received the command "Safe to fire" from the safety officer, either by oral expression or on a prearranged signal. When it is unsafe for any piece to fire as laid and loaded, the safety officer must inform the battery executive of the fact and reason therefor; for example: "Unsafe to fire, No. 4 is 30 mils left of left safety limit" or "Unsafe to fire, maximum elevation with charge 5, site 315, is 360."

8. PRECAUTIONS FOR SAFETY AT BATTERY POSITION. Unless the impact area is very extensive, the safety officer should take certain measures for safety which will assist in the accomplishment of his mission. Some of these measures are:

a. After the battery is emplaced, to mark the lateral safety limits of each piece on the ground with stakes and then determine safety limits of direction for each piece in terms of shifts from base deflection.

b. To determine the maximum and minimum ranges and elevation settings for each projectile which may be used; corrections from registration must be considered in determining range limits.

c. To inform the battery executive of the shifts from base deflection and the instrument settings which mark the safety limits, direction, and range for each piece.

9. MEASURES TO PREVENT DELAY BY SAFETY OFFICER. If, in the opinion of the officer in charge of firing, the state of training of the firing battery is sufficiently advanced, he may authorize the safety officer to check only on the safety of the commands sent to the battery. Responsibility for their proper execution rests entirely with the battery executive and chiefs of section. When this step is taken, the safety officer will:

a. Assure himself that the battery is in the proper position.

b. Assure himself that he has the proper safety card.

c. Mark on the ground the deflection safety limits of each piece.

d. Verify that each chief of section knows the location of deflection safety markers for his piece, and that he has a written notation of deflections, of minimum time setting, and of maximum and minimum ranges and elevations, outside of which the piece may not fire.

e. Verify the initial laying of the battery.

f. Prohibit the execution of any command which will cause fire to fall outside the safety limits.

10. SUMMARY. The safety officer and his assistants are detailed to minimize the possibility of accidents; they are not detailed to check and correct inaccuracies in the laying of the pieces. The safety officer is concerned only that the pieces are loaded and laid safely, and he and his assistants must perform this duty with the least interference with the execution of fire. The responsibility for the accurate execuion of fire commands rests on the battery executive and the personnel of the firing battery. The state of fire discipline in a battery which reduces the possibility of error in the execution of fire commands is established by the personal leadership of the officers and noncommissioned officers and by continuous insistence on accuracy during all phases of training in the service of the piece and in execution of fire.

Section II. CONDUCT OF SERVICE PRACTICE

11. TRAINING PROGRAMS. The training directive or training program issued by the Commanding General, Army Ground Forces, or lower echelon of command for any training period, will usually specify the percentage of the total allowance of ammunition allotted to each type problem. When percentages are not prescribed in training programs, the following allotment of ammunition by percentages to type problems is suggested as a balanced program for the service practice of a battalion:

PROBLEMS, TYPE OF ADJUSTMENT	PERCENTAGE OF AMMUNITION ALLOWANCE			
	105-MM HOW TOWED	105-MM HOW SP	155-MM HOW; 4.5-INCH GUN	HEAVY
Axial Precision	3	3	6	9
Axial Bracket	2	9	6	5
Small-*T* Precision	11	4	14	12
Small-*T* Bracket	15	9	7	8
Large-*T* Precision	2	2	9	4
Large-*T* Bracket	4	6	5	2
Air Observation	3	4	5	10
Forward Observation	16	26	9	6
Moving Targets, direct laying	10	14	6	3
Observed Fire Chart, battalion concentration after adjustment of one battery	8	9	8	3
Fires Prepared from a Firing Chart, high burst registration	3	1	3	8
Center of Impact Adjustment	3	1	3	5
K-transfer of Fire	14	10	11	15
Fires Prepared from Map Data Corrected	6	2	8	10

12. CONDUCT OF SERVICE PRACTICE.

a. Field artillery service practice should be conducted under the direction of the battalion commander. The battalion is the fire unit, and the training of battalion personnel in preparation, execution, and conduct of fire is the responsibility of the commander.

b. Whenever possible, service practice should be the continuation of a tactical field exercise which requires that the artillery unit occupy a position and open fire in support of the action of the force it supports. Following the tactical occupation of position by the field artillery unit, the officers may be assembled at a single observation post for instruction in preparation and conduct of fire. Such service practice should be conducted as the examination phase for officers qualified to conduct fire and as the demonstration phase for those officers who are not qualified. The firing of service ammunition to teach techniques of preparation, execution, and conduct of fire is an unnecessary and wasteful procedure. The techniques must be taught and fire discipline must be established by training in the gun park, in the classroom, in nonfiring exercises, and by the use of terrain board, terrain plot, field artillery trainer, and subcaliber attachments. When service ammunition is fired, special attention must be given to technique of observation, since instruction in observation and sensing cannot be duplicated on terrain boards or on other mechanical devices.

13. OBSERVATION POSTS.

a. Even though the training program specifies the expenditure of a certain percentage of the ammunition allowance on unobserved fires, rounds used to check data should be kept to a minimum and should be observed. It is usually practical to verify the accuracy of battalion concentrations which have been prepared as *K*-transfers or from map data corrected by assigning missions requiring the adjustment of observed fire on features within the concentration areas.

b. The observation post for service practice should be organized so that each officer has observation of the impact area equal to the observation of the officer selected to conduct fire. The officer conducting fire should be required to announce his sensings and fire commands in a tone loud enough to be heard by all officers attending the service practice or, if this is not practical, sensings and commands should be relayed or a record should be kept on a blackboard in sight of the observers. All officers attending a service practice must be kept fully informed at all times of the commands issued by the officer conducting fire to the extent that any observer should be capable of taking over the problem at any point and completing the adjustment.

c. The observation post should be selected with consideration to conditions encountered in combat. For the long range weapons, training must be stressed on long range observation.

14. ASSIGNMENT OF FIRE MISSIONS.

a. The officer directing fire during service practice should prepare and assign fire missions which logically follow the assumed tactical situation. This procedure will require careful planning and preparation, if the full tactical value of service practice is to be gained.

b. The officer directing fire should describe the special tactical situation and the target in such detail that the officer selected to conduct fire will have sufficient information on which to base a decision regarding the proper method of attack. The officer selected to conduct fire should be designated as a forward observer, battery commander, or other officer of a field artillery unit, in accordance with the tactical situation; and the officer directing the fire should assume any role necessary to present the fire mission in a realistic manner. Whenever practical, if the tactical situation is based on the action of a battalion, the special situation should be presented in such a manner that the officer selected to conduct fire will be required to report the target to the fire-direction center and to request the proper fire; or if the tactical situation is based on the action of a battery, to determine the firing data and adjust fire employing the proper methods to place the fire on the target at the proper time.

15. ECONOMY OF AMMUNITION. The allowance of ammunition for service practice is always limited and every effort should be made to avoid any expenditures which do not contribute to combat training. The following methods assist in the conservation of ammunition.

a. Simulated sensings during adjustment. Rounds fired as a result of commands that will not contribute to the adjustment, nor to the instructional value of the problem, often can be saved. The operator is instructed to withhold command for range or elevation on hand signal from the officer directing fire. The fire is held up in this fashion, and the officer firing is told where the round (s) would have fallen. Care must be exercised that this interruption does not disrupt the continuity of the problem.

b. Simulated sensings during fire for effect. In a precision problem for destruction, the officer directing service practice may simulate all or part of the sensings after the trial elevation has been obtained. The officer conducting fire acts on the simulated sensings to compute the adjusted elevation. In the same manner, the fire for effect may be simulated in problems requiring a bracket adjustment. The fire is

stopped after the adjustment is complete and the officer conducting fire is given simulated sensings based on his commands for fire for effect. It must be remembered, however, that adjustment continues during fire for effect. Instruction in this important and difficult technique must not be abandoned in an effort to save ammunition.

16. CRITIQUES.

a. Good instruction at service practice requires that the officer directing the practice should be capable of conducting a critique which presents intelligent, tactful, and constructive criticism of each problem fired. Critiques should be impersonal, specific, and limited to essentials. The officer directing the service practice must be qualified professionally and especially skilled in preparation and conduct of fire. It is possible that an officer may forgive sarcastic criticism or even ridicule directed at him during a critique if the criticism is professionally sound; but the inability of the officer directing service practice to recognize, appreciate, and discuss a skillful demonstration of professional proficiency at service practice is definitely more harmful to the training and morale of the individual and the unit. Neither sarcasm, ridicule, nor lack of professional ability should be tolerated in an officer charged with the direction of service practice.

b. Following each fire mission, a critique should be held at once which should be conducted generally in the following order:

(1) A brief description of the tactical situation including the location of the elements of the supported unit. A description of the target. A statement of the *assigned mission.*

(2) A concise statement of whether the mission was accomplished.

(3) Discuss the essential reasons why the mission was (or was not) accomplished.

(4) Point out, discuss, and praise any actions or techniques which demonstrated especial skill in preparation or conduct of fire.

(5) Ask the officer who has fired whether he has any comments to add to the critique.

(6) Encourage the officers observing the service practice to ask questions or to bring up pertinent points for discussion. If necessary, the officer directing service practice should ask questions which will direct the discussion towards the basic principles of conduct of fire.

APPENDIX II
CALIBRATION

1. GENERAL. Calibration is the comparison of the shooting qualities of a given piece with those of another piece accepted as standard. *Absolute calibration* is the comparison with a piece that gives firing table results under standard conditions. *Comparative calibration* is the comparison with a reference piece selected as standard; this is the usual type of calibration. A *calibration correction* is a correction applied to range or elevation to make a piece fire in agreement with a reference piece. It may be given in the form of a *K*-correction or a *VE*-correction. The comparative calibration corrections applicable to one charge are not necessarily applicable to another charge. A *short-shooting* piece with one particular charge may even become a *long-shooting* piece with an adjacent charge. If possible, weapons should be calibrated with all charges.

2. NECESSITY FOR CALIBRATION. The principles of conduct of fire are based on the assumption that if all pieces of a unit are fired under the same conditions (same ammunition lot, charge, fuze, quadrant elevation, and weather conditions) the rounds will fall at approximately the same range. This assumption usually is not true because of variations in the shooting qualities of the pieces. The variations are due to slight differences in the dimensions of the powder chambers and in wear in the tubes. When the variations are determined by calibration, compensating corrections may be made for individual pieces, or the pieces of a battalion (or larger unit) may be regrouped and allotted to batteries in accordance with their shooting qualities, in which case compensating corrections are applied by battery. The latter procedure is preferable.

3. ORDNANCE CALIBRATION.

a. Mechanical calibration. This is performed by ordnance personnel. It is the determination, by measurement and computation, of the percentage of wear in the forcing cone and tube of the piece. If pieces are grouped in accordance with the percentages of wear, the pieces of any particular battery will have velocity errors of approximate-

ly the same magnitude. However, the numerical values of such errors, and consequently the compensating corrections in the form of a *K* or a *VE,* cannot be determined without firing.

b. Chronograph units. Calibration may be performed by ordnance chronograph units, properly equipped to make direct measurements of muzzle velocity. This method permits the determination of a *VE* for each piece for any one ammunition lot. A comparative calibration is obtained from these measurements.

c. Wear tables. When wear tables are available for high velocity weapons, calibration data can be corrected according to the drop in muzzle velocity expected as a result of the firing of a certain number of equivalent rounds. (An equivalent round is a round using maximum charge, or a number of rounds of a lower charge producing the same wear on the tube as a single round of maximum charge.) The actual wear rate may vary in particular tubes as much as 50% in either direction from the values in the tables. A new calibration is made when the correction due to wear has become large since the last calibration. These tables can be used to correct calibration data between periods of complete calibration. They give the expected loss in muzzle velocity for a round fired with a certain type of ammunition. These corrections for *VE* should be made periodically (about every 10 service rounds fired). An accurate record of this firing should be kept in the gun book of the piece, and calibration corrections obtained therefrom should be kept at the battery and at the battalion fire-direction center.

Example: 8-inch gun number 139 has been calibrated at normal charge M9, and at supercharge M10, and the following effects obtained:

Normal charge M9, —13 feet per second.

Supercharge M10, —28 feet per second.

The piece fired eight rounds of normal charge M9, and eight rounds of supercharge M10.

Total equivalent full charge $(8 \times .526) + 8 = 12$.

Loss in muzzle velocity, $12 \times .24 = 2.9$, or 3 feet per second for normal charge M9.

Loss in muzzle velocity, $12 \times .4 = 4.8$, or 5 feet per second for supercharge M10;

Corrected *VE*: normal charge M9, $(-13) + (-3)$, or -16 feet per second;

Corrected *VE*: supercharge M10, $(-28) + (-5)$, or -33 feet per second.

4. CALIBRATION BY FIRING.

a. Conditions. An adjusting point is selected on fairly level ground at a range which is average for the charge to be used. Pieces are so placed that their respective ranges and sites to the adjusting point are the same. Ranges and sites are determined accurately, and data for standard conditions are computed for fire on the adjusting point. Gunner's quadrants are checked against a master quadrant and are made to agree with it. The on-carriage quadrant of each piece is made to check with the gunner's quadrant for that piece. Bilateral observation is established for the accurate location of each round. A flash unit from the observation battalion may be used for this purpose. As an alternate procedure, flank observers are posted to record the deviation of each round with respect to an adjusting point. A scale in hundreds of yards, materialized on the ground, will assist the flank observers in determining the amount of error of each round.

b. Firing. Each piece fires with the same type, lot, and weight of projectile and the same powder lot, charge, and fuze. After two warming and seating rounds, each piece fires a group of six or more rounds at the computed quadrant elevation; the distance from the piece to the center of impact is determined from the deviations reported. *K* or *VE* for each piece is computed. The pieces should be fired in succession by salvo to reduce the effects of weather. The firing of all pieces should be completed within as short a space of time as consistent with accuracy to insure that all firing is under the same weather conditions. If the *VE* of the ammunition fired is known, it should be subtracted from the *VE* determined by firing. This method gives a *VE* of the piece and does not include the *VE* of the ammunition.

c. Grouping pieces into batteries. After a *K* or *VE* for each piece in a battalion has been computed, the pieces are grouped into batteries so that one battery will have the four strongest, another the four weakest, and the third the four of average shooting strength. As an exception, two batteries may contain pieces of approximately equal shooting qualities, and one battery may have the very long and very short range pieces. Since the corrections may not be of the same magnitude, nor in the same direction for all charges, pieces are grouped according to their performance with the charge most frequently used.

d. *K* for various charges. To determine the *K* or *VE* for various charges, only the reference piece of the battery of average strength need be fired.

5. APPLICATION OF COMPARATIVE CALIBRATIONS.

a. The piece which has the longest range in each battery is used as the reference piece (should be used as the base piece). Small dif-

ferences among the pieces of the battery are neglected. This procedure results in the calibration corrections for the other pieces of the battery being of the same sign. Also, the additional wear on the base (strongest shooting) piece will reduce its shooting strength below that of one of the other pieces of the battery. Thus, the base piece should be rotated and even wear of the pieces of the battery should result.

b. So that all batteries can use corrections determined by the registration of one battery, the comparative calibrations must be considered.

Example 1: A *K* of +30 yards per 1000 yards has been determined from registration by a battery. Another battery is known to shoot 15 yards per 1000 yards weaker than the registering battery. The weaker battery uses a *K* of +45 yards per 1000 yards.

Example 2: For charge 5 (105-mm howitzer M2), the *VE* of the base piece of Battery A is −24 feet per second, and the *VE* of Battery B is −46 feet per second. An adjusted elevation of 316 mils results when Battery B registers at map range 5200. The GFT of computer B is set with range 5200, elevation 316. The elevation correction for the difference in *VE*s equals $\left(\frac{+7.3 \times -22}{13}\right) = -12$ mils. The GFT of computer A is set with range 5200, elevation 304.

c. Calibration corrections between batteries are applied by the fire-direction center. Calibration corrections among the pieces of a battery may be applied by the battery executive. To facilitate rapid computation of data, the battery executive may apply range calibration corrections as a constant correction to site, and time calibration corrections as a constant correction to the announced time setting. The battery computer (instead of the executive) may apply calibration corrections to the data sent to the guns, thus giving more accurate data at all ranges for special targets or weapons.

6. CALIBRATION OF A GROUP OF BATTALIONS. To determine the calibration corrections among battalions equipped with the same weapon, it is necessary only to determine the calibration corrections among the reference pieces of the average batteries of the battalions.

APPENDIX III
DEAD SPACE AND VISIBILITY

1. DEAD SPACE.

a. General. The near limit of the dead space is the *grazing point.* The far limit of the dead space is the first point of impact beyond the near limit. The determination of dead space is possible only with an accurate, contoured map.

b. Quadrant elevation method. To determine dead space by the quadrant elevation method, the procedure is as follows:

(1) Draw a ray from the plotted position of the piece through the mask. By inspection, determine the grazing point of the mask considered. Determine the quadrant elevation of this point. For greater accuracy, determine also the quadrant elevations of points on the ray that are 50 to 100 yards short or over the initial grazing point tested; the point requiring the greatest quadrant elevation marks the beginning of dead space.

(2) The point of impact, or end of dead space, is determined by finding a point beyond the mask which requires the same quadrant elevation as that of the grazing point. The process is one of trial and error. A test point of impact is selected by inspection, based on the range corresponding to the quadrant elevation for the grazing point. The quadrant elevation for the test point is determined; if it is less than that for the grazing trajectory, the point is in dead space; if greater, the point is beyond dead space. By repeating the process, the point of impact may be determined to any desired degree of accuracy.

c. Dead space chart. The dead space for one ray or profile is determined; the process is repeated for such additional rays as are necessary. The dead space area is outlined by connecting corresponding points on adjacent rays.

2. VISIBILITY. For discussion of visibility and visibility charts see FM 21–26.

APPENDIX IV
USE OF FIELD GLASSES

1. GENERAL. The following instructions on the use and care of the Binocular M3 (6 power) apply, with slight modification, to all military field glasses.

2. DESCRIPTION.

a. The reticle has a horizontal mil scale, graduated 50 mils right to 50 mils left of the center of the field of view. Above the horizontal line are two series of reference marks; these marks are spaced 5 mils apart for convenience in observing fire. The vertical scale, graduated in hundreds of yards, is used by infantry organizations and has no application to other than rifle firing.

b. The neck strap, secured to the strap loops of the instrument, protects the instrument from accidental falls and keeps it within easy reach. A russet leather carrying case, with carrying loop and shoulder strap, protects the instrument when it is not in use. The instrument is carried in the case with the objective end up. When replacing the binocular in the case, the diopter scale setting need not be disturbed, but the hinge may need adjusting.

3. OPERATION.

a. Setting interpupillary distances. To set the binocular so that the eyepieces are the same distance apart as the observer's eyes, first look through the glass at some fairly distant object, then open or close the glasses at the hinge until the fields of view merge and appear to be one sharply defined circle.

b. Focusing. Look through the eyepieces, both eyes open, at a fairly distant object. Place a hand over the front of one telescope and screw the focusing nut of the other in or out until the object is sharply defined. Repeat for the other eye. Then note the diopter scale reading on each eyepiece; a similar setting on the eyepieces of any other field glass will accommodate the observer's eyes. Avoid touching the objective lens. *Memorize each of these settings.*

4. CARE AND PRESERVATION.

a. The binocular is rugged in construction but should not be subjected to rough handling.

b. The instrument is not to be disassembled by the using arm. Repairs involving disassembly or painting are to be referred to ordnance maintenance personnel.

c. The instrument should be carefully wiped dry immediately after use in wet weather and returned to the carrying case provided. *Optical surfaces are to be carefully wiped with lens tissue paper.*

5. RULES FOR USE OF BINOCULARS.

a. Memorize your interpupillary distance and the diopter scale for each eye.

b. When borrowing binoculars from another, note the interpupillary distance and diopter scale setting. When returning the binoculars, set these settings on the binoculars to spare the lender the annoyance of changing the settings.

c. Never use force in returning the binoculars to the case. Learn the setting on the interpupillary distance scale which allows the binoculars to be returned to the case with ease.

d. Hold the glasses in both hands, placing the first joint of the thumb outside the eyepiece, and then snugly hold the eyepiece against the eye socket, thus eliminating undesirable glare.

e. Pick out a conspicuous feature near the target to be used as a reference point to aid in quickly finding the target with the glasses.

APPENDIX V

COMMON MISTAKES AND THEIR PREVENTION OR DETECTION

1. AIMING CIRCLE.

a. Common mistakes.

(1) Failure to note that turning the azimuth micrometer has moved the azimuth index to the wrong hundred, thus setting, for example, 5541 instead of 5441.

(2) Setting, for example, 3697 instead of 3597 because the azimuth index is near 36.

(3) Turning the lower motion instead of the upper motion, or vice versa.

(4) Failure to clamp the two clamping screws and the wing nut.

(5) Bumping the instrument or tripod.

(6) Having on the person objects containing magnetic metals.

(7) Counting mils in the wrong direction from a numbered graduation on the azimuth micrometer scale, thus setting, for example, 2373 instead of 2367.

(8) Failure to level the bubble.

(9) Failure to follow the prescribed procedure for the elimination of lost motion.

b. Prevention. Formation of proper habits in training (consisting principally of checking operations and insisting on exactness).

c. Detection. Independent checks, repeated readings, reading settings, check of final direction by azimuth.

2. TRANSIT.

a. Common mistakes.

(1) Same as paragraphs 1a (3), (4), (5), (9).

(2) Reading the supplement of an angle because the wrong figures on the horizontal limb have been read.

(3) Reading in the wrong direction on the vernier.

b. Prevention and detection. Same as paragraphs 1b and c.

3. OTHER OPTICAL INSTRUMENTS (INCLUDING SIGHTS). Similar to paragraph 1.

4. TAPING.

a. Common mistakes.

(1) Getting wrong number of tape lengths because pins were lost or miscounted, or counting number of tape lengths different from the number of pins.

(2) Becoming confused in breaking tape.

(3) Reading final part of tape length from wrong end of tape.

(4) Including that part of tape beyond the graduations.

(5) Taping in feet and plotting the same amount as yards.

b. Prevention. Same as paragraph 1b.

c. Detection. Rough check by pacing. Closing traverses.

5. NUMBERS.

a. Common mistakes.

(1) Garbling of numbers by inversion (as for example 12,475 instead of 14,275).

(2) Garbling of numbers because digits were misunderstood or forgotten.

(3) Decimal points in wrong place.

(4) Wrong addition and subtraction.

(5) Error in plus and minus signs.

b. Prevention and detection.

(1) Avoiding mistakes set forth in subparagraphs a (1) and a (2) above; habitually recording; pausing after three digits for a repeat back; habitually repeating back. For example, the proper method of sending (56.83—46.28) is: Five six point, (repeated by receiver); eight three dash, (repeated by receiver); four six point, (repeated by receiver); two eight, (repeated by receiver).

(2) Items (3), (4), and (5) in subparagraph a above. Independent checks and rechecks.

6. PLOTTING.

a. Common mistakes.

(1) Using 1/21,120 instead of 1/20,000 scale.

(2) Using 1/25,000 instead of 1/20,000 coordinate scale on 1/25,000 map having 1.8-inch point designation grid.

(3) Reversal of observer sensing; for example, plotting "BP is 500 left" as 500 yards left of base point.

(4) Same as paragraphs 5a (1) and (2).

(5) Considering the subdivided 1000 as being included in the numbered thousands.

(6) When on the north side of the map, plotting the increment from the wrong grid line or in the wrong direction.

(7) Putting the center of the protractor over the wrong point.

(8) Reading azimuths 1600 or 3200 mils in error.

b. Prevention. Covering scales which should not be used; formation of proper habits in training.

c. Detection. Independent check or supervision.

7. RANGE-DEFLECTION FAN.

a. Common mistakes.

(1) Confusing right and left shifts.

(2) Wrong hundreds of mils shift.

b. Prevention.

(1) Rule of thumb: right for right edge of fan, left for left edge of fan.

(2) Formation of proper habits in training.

c. Detection. Comparison; supervision.

8. GFT.

a. Common mistakes.

(1) Wrong slide or charge.

(2) Same as paragraphs 5a (1) and (2).

(3) Using drift instead of *c*, or vice versa.

b. Prevention. Formation of proper habits in training.

c. Detection. Comparison; supervision; calling for computers to read off their *K*'s.

9. EXECUTION OF FIRE COMMANDS.

a. Common mistakes.

(1) Wrong charge.

(2) Time which is whole seconds in error, or fraction of second in wrong direction from numbered graduation; wrong corrector when using fuze setter.

(3) Executing RIGHT 300 instead of SITE 300.

(4) Many possible errors with reference to deflection and deflection difference.

(5) Failure to correct for lost motion as prescribed.

(6) Same as paragraphs 5a (1) and (2).

(7) Failure to level all bubbles.

(8) Setting wrong elevation, site, or quadrant elevation.

b. Prevention. Formation of proper habits in training.

c. Detection. Independent check of charge and fuze within the section; frequent check of settings by executive; use of "ESS-EYE" instead of "SITE."

10. MISCELLANEOUS.

a. Common mistakes.

(1) Choosing a complex or difficult method when a simple method is available.

(2) Use of methods inconsistent with accuracy sought.

(3) Failure to associate numbers with the corresponding installation.

(4) Wasting time and ammunition, and losing effect on the target.

b. Prevention. Use of initiative and judgment; use of prescribed procedures; taking time to select the most effective plan.

APPENDIX VI
METHODS OF MIL-GRIDDING OBLIQUE PHOTOGRAPHS

Section I. GENERAL

1. DEFINITION. *Mil-gridded obliques* are photographs taken with a tilted camera, on which has been printed an angle measuring grid. Accurate placing of the grid requires the presence of the horizon on the picture, which limits the angle of tilt.

2. DESCRIPTION.

a. A mil-gridded oblique is made by contact-printing the negative through a superimposed transparent mil grid (fig. 168). The interval between grid lines is 20 mils horizontally and vertically. The vertical grid lines represent portions of the rays of a huge imaginary fan placed over the terrain. The apex of the grid is called the plumb point; it indicates the geographic location of the camera at the instant the photograph was taken.

b. Methods of using mil-gridded obliques are described in paragraphs 201 to 206.

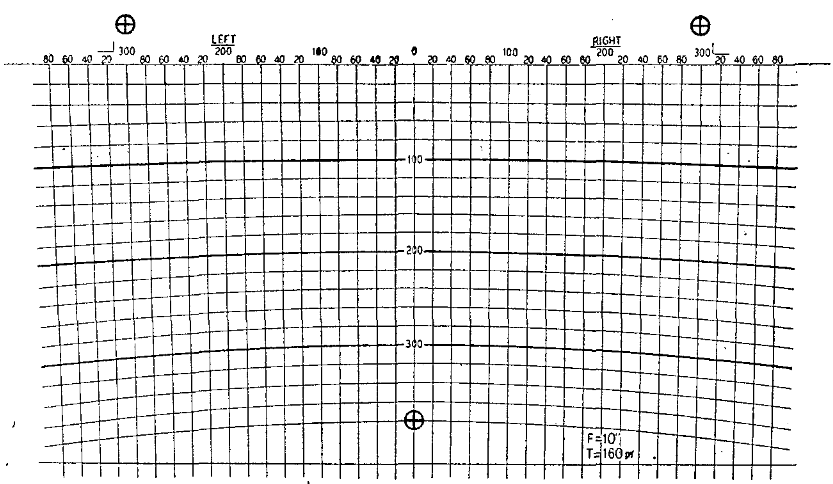


Figure 168. Mil grid for an oblique photograph.

Section II. CONSTRUCTION OF GRIDS

3. THE ANGLE MEASURING OBLIQUE GRID.

a. The shape of the grid as it appears on a particular photograph depends upon two factors:

(1) The *tilt* or depression of the optical axis of the camera below the horizontal at the instant of exposure.

(2) The focal length of the camera lens.

b. (1) The sketch in figure 169 shows the general layout on a drawing for plotting points. Draw the line of zero vertical angle, and perpendicular to it draw the center line. At an arbitrary distance, *K*, in inches, construct a line parallel to the line of zero vertical angle. To draw the vertical lines of the grid, compute the lateral displacements from the center line on the line of zero vertical angle (distance *S*) and on the construction line (distance *W*), for a series of values of horizontal angles (*H*), such as 20, 40, 60 mils, and so on, from the formula:

$$S = \frac{f \times \tan H}{\cos T} \qquad \text{(formula 1)}$$

$$W = S - (K \times \sin T \times \tan H) \qquad \text{(formula 2)}$$

in which f = focal length of the camera, in inches;

T = angle of tilt of the camera, in mils (measured with the with the horizon-tilt template).

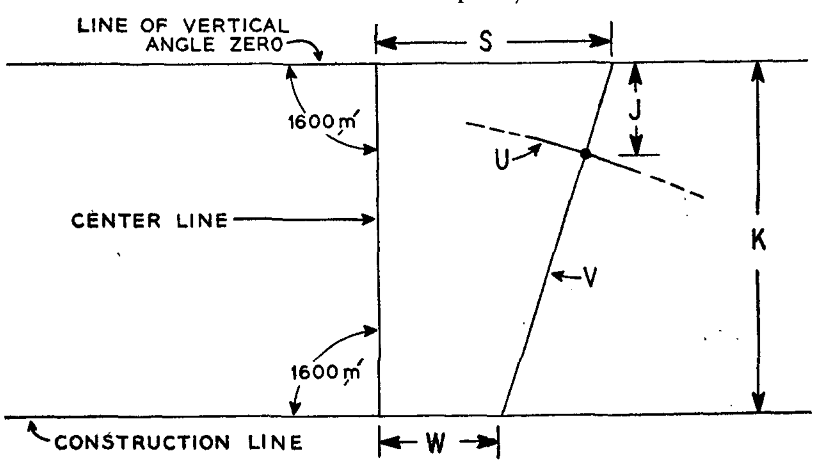


Figure 169. Construction of an oblique grid.

(2) To locate the horizontal lines, their intersections with the vertical grid must be plotted and smooth curves drawn through the plotted points. The intersection or vertical angle line U with vertical grid line V is a distance J, in inches, from the line of zero site. The formula for J is as follows:

$$J = \frac{f}{\sin T \times \cos T\ (\cos H \times \cot D \times \cot T + 1)} \qquad \text{(formula 3)}$$

In this equation, D is the vertical angle represented by curve U, and H is the value of the horizontal angle represented by line V. Fix a value for D, then plot the intersections with V at $H = 0$, 60, 120, 180 mils, etc. Repeat this for successive curves with D as 20, 40, 60 mils, and so on, for the entire horizontal grid system.

(3) The grid drawing will produce better results if it is made to an enlarged scale, using black lines on white paper. Photograph the drawing down to proper size, and make a positive on a film base by contact printing.

4. PLATE GRID.

a. Because of the motion of the airplane, the pointing of the camera will very seldom be in the exact desired direction. In addition to affecting the tilt, the unsteadiness of the plane can be responsible for the presence of dip in the pictures. Dip is comparable to the cant of a field piece. It is defined as the angle between the horizontal axis of the photograph (the line joining the left and right tick marks) and the true horizon. The plate grid (fig. 170) is used to measure tilt and dip to correct the simultaneous vertical to locate the plumb point. The center section of the plate grid is a graphical representation of angles measured at the lens of the camera materialized on the photographic plate.

b. Construction of the plate grid is begun by drawing perpendicular lines to represent the horizontal and vertical axes of the camera plate (fig. 171). The distance Z is computed by the formula:

$$Z = f \times \tan L \qquad \text{(formula 4)}$$

in which Z = distance from principal point along vertical or horizontal axis, in inches;

L = horizontal or vertical angle in mils;

f = focal length of camera, in inches.

Values of Z_1, Z_2, Z_3, etc., are computed for the horizontal and vertical angles desired (such as 20, 40, 60 mils, and so on), and these distances are marked along the horizontal and vertical axes of the plate. The grid is then completed by drawing perpendicular lines through the marks on the axes (see fig. 170). Extensions of the vertical scale along the vertical axis are computed from formula 4. The fan portion of the plate grid is a true angular mil scale whose center is the principal point of the photograph.

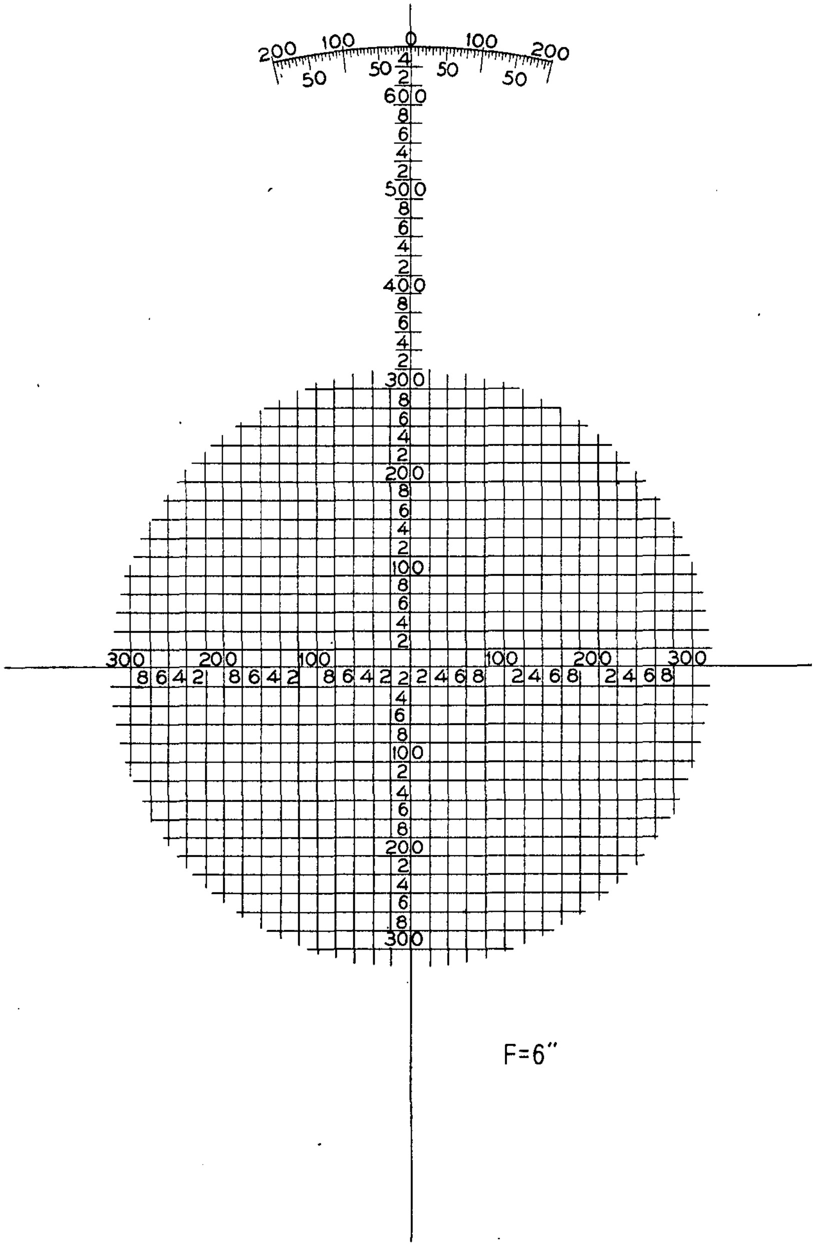


Figure 170. Plate grid.

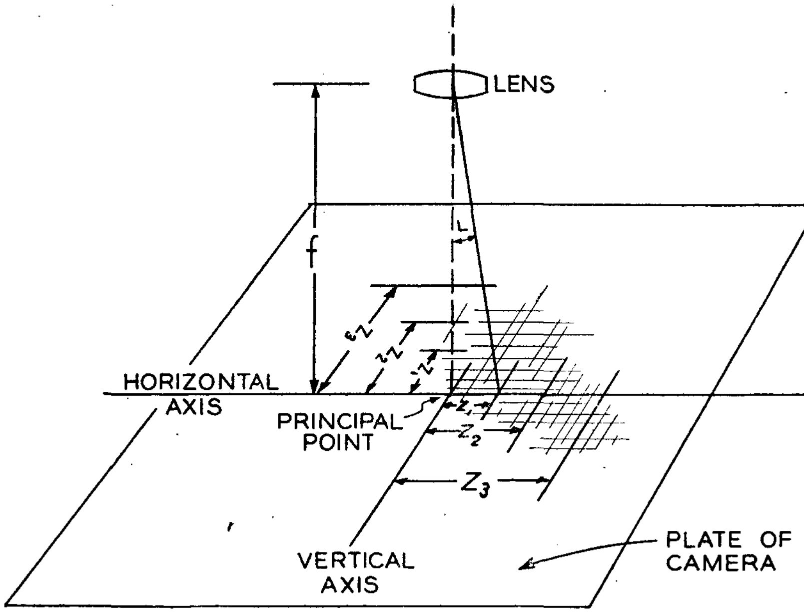


Figure 171. Construction of plate grid.

c. The center section of the plate grid is used in applying tilt and dip variations when the plumb point is located on the simultaneous vertical (par. 8 below). The vertical scale extended is used to measure the tilt of the photograph. Dip is measured with the fan portion of the plate grid. Better results in producing the grid will be obtained if it is originally drawn to an enlarged scale using black lines on white paper. Reduce for use as described in paragraph 3b (3) above.

5. HORIZON-TILT TEMPLATE.

a. This template (fig. 172) is used to determine the location of the true horizon with respect to the apparent horizons of pictures taken at different altitudes, and to measure the tilt of the camera axis below the horizontal plane.

It is composed of the horizon lines and the tilt measuring scale. The upper, or zero horizon line, represents the true horizon line corrected for refraction and earth curvature; the other parallel lines represent the apparent or pictured horizons (fig. 173) for camera altitudes (in feet) corresponding to the numbers thereon drawn at distances below the true horizon line, determined by the formula:

$$d = f \times \tan T - f \times \tan (T - Y) \qquad \text{(formula 5)}$$

in which $Y = 58.8 \sqrt{A}$

d = distance in inches;

f = focal length of camera in inches;
T = angle of tilt, in seconds, from the horizontal;
A = altitude in feet of the photograph above the general terrain level.

The quantity Y is expressed in angular seconds.

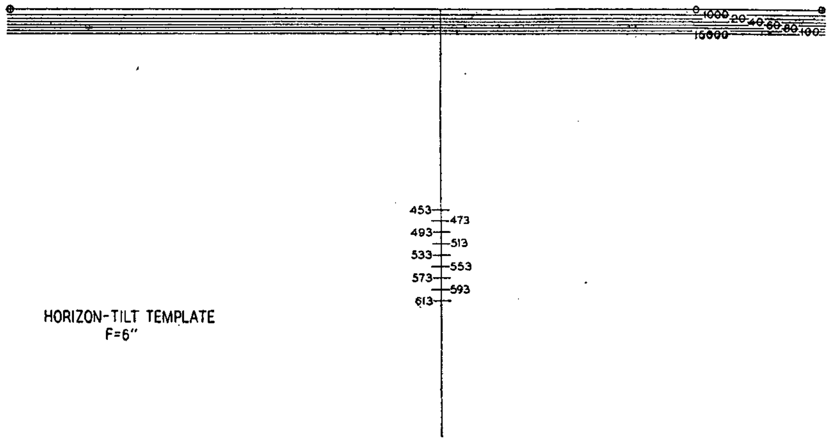


Figure 172. Horizon-tilt template.

The tilt measuring scale is computed from formula 4 above, as is the tilt measuring scale of the plate grid. The distance computed, however, is laid off *down* the vertical line of the template from the zero horizon line.

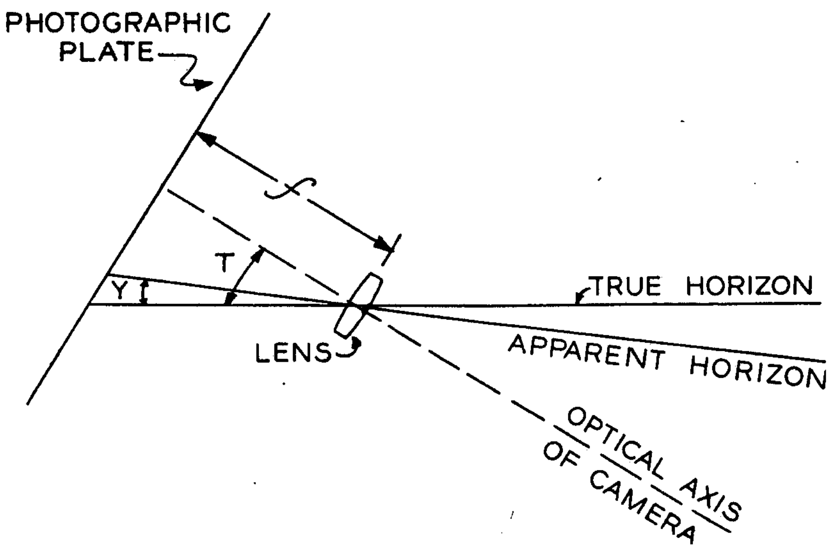


Figure 173. Explanation of terms of formula 5 (par. 5a).

b. The same general rules for producing the grid listed in paragraph 3b (3) above are applicable to producing the horizon-tilt template.

6. ORIENTATION OF GRIDS.

a. Selection of grid. As was stated in paragraph 3, the shape and size of an oblique grid is dependent on the tilt of the camera axis below the true horizon at the instant the picture was taken, and the focal length of the lens. As oblique photos are taken at as nearly a predetermined angle of tilt as the motion of the airplane will permit, time will be saved in gridding photographs if a small set of standard grids is kept at each reproduction agency.

The procedure for selecting the proper grid from a stock on hand is: the oblique negative is placed on a viewing box or on a piece of white paper on which are drawn two lines perpendicular to each other and long enough to extend beyond the negative. Over these, the collimation tick marks on the negative are alined. The intersection of the perpendicular lines marks the center or principal point of the negative. The horizon-tilt template is placed on the negative so that the vertical line of the template passes through the principal point of the negative, and the horizontal line corresponding to the altitude at which the photograph was taken is superimposed upon the apparent horizon. With the horizon-tilt template thus oriented, pin pricks are made at each end of the zero horizon line through the template and negative. The holes in the negative identify the correct position of the true horizon line of the oblique. The angle of tilt is read from the vertical scale opposite the principal point of the negative. This step identifies the proper oblique grid and enables the selection of one from a set on hand. If no grid on hand has been prepared for a tilt angle within approximately 10 mils of the tilt, as measured, then a grid should be constructed in accordance with the method described in paragraph 3.

b. Placing oblique grid on negative. The oblique grid, selected or prepared as described above, is superimposed on the negative so that the zero vertical angle line passes through the pin pricks of the zero horizon line, and the center line of the grid passes through the principal point of the negative. The negative and grid are taped together and pin pricks made through the three orientation points of the oblique grid (shown on fig. 168 as small crosses enclosed in circles). The grid and negative are placed in the printer, and the desired number of prints is made. The pricking of the grid to the negative furnishes a means whereby the orientation may be duplicated if reprints are desired.

7. PERSPECTIVE GRID.

a. To construct a perspective grid for oblique photographs gridded with an angle measuring grid, proceed as follows:

(1) On a transparent sheet or white paper, draw a horizontal line, with a perpendicular to it at the center. These represent, respectively, the true horizon line and the center line of the oblique.

(2) Construct a range line at each of the desired ranges (R) parallel to the true horizon line and Q inches below it, where (see fig. 174):

$$Q = f/\cos T \left(\frac{1}{\sin T + (R/h) \cos T} \right) \qquad \text{(formula 6)}$$

f = focal length of camera (in inches);

T = angle of tilt of camera in mils (measured with horizon-tilt template);

h = height of camera above ground (in yards);

R = desired range (in yards).

(3) Mark on any range line (preferably one well below the true horizon line) the intersection with this range line of the lines parallel on the ground to the center line and at a ground distance of d yards from it. These intersections appear on the range line a grid distance of P inches from the center line, where (fig. 169):

$$P = (d/h)\, Q_R \cos T \qquad \text{(formula 7)}$$

d = desired ground distance right or left of the center line in yards;

Q_R = Q as found above for the range line used.

(4) Draw lines through these intersections to the intersection of the true horizon and center lines of the oblique grid.

b. The grid is now complete. However, since the altitude of the airplane was not known accurately, and since distances in the photo are approximately proportional to the altitude, a photo-ground relationship should be set up as soon as possible by comparing a known ground distance with its photo measurement. This is similar to establishing the photo-ground relationship in ordinary photomap reading. The grid may be reproduced in the proper size on a positive transparent sheet by photographic means.

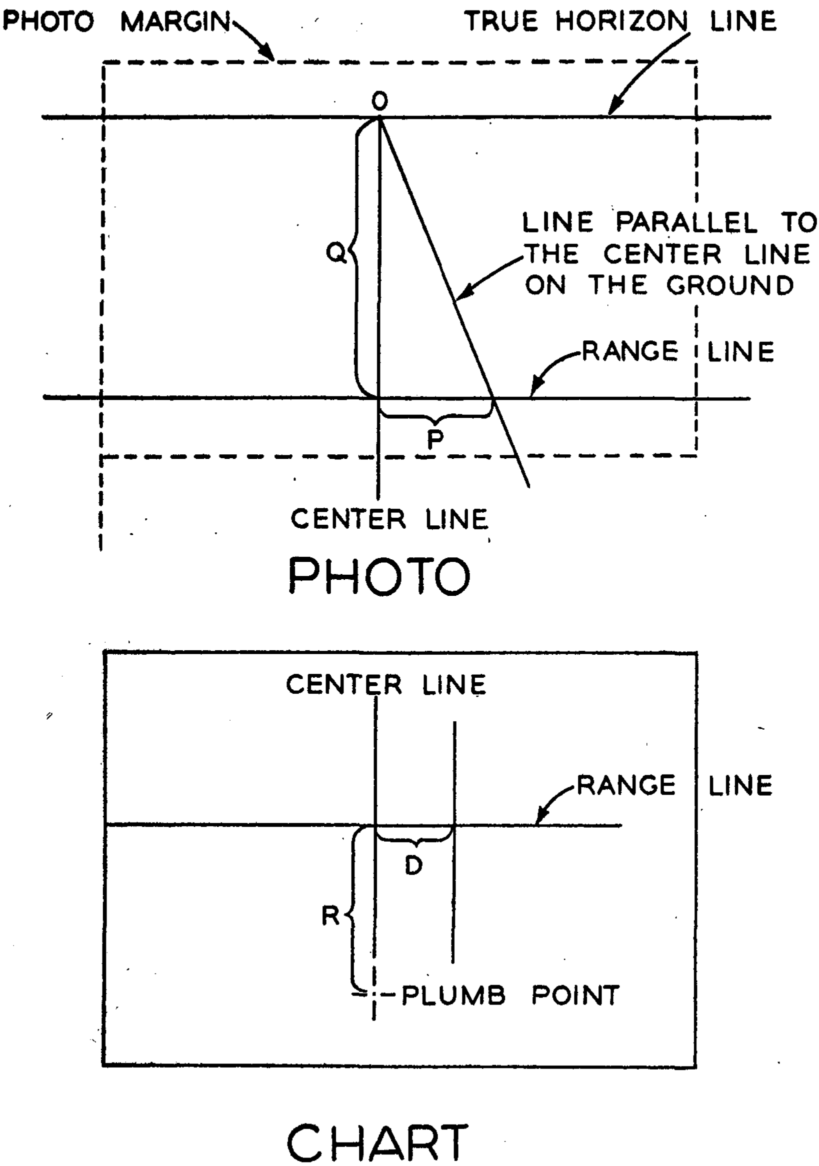


Figure 174. Construction of perspective grid transparent sheet.

8. CORRECTION OF VERTICAL PHOTO FOR TILT AND DIP.

a. If the optical axis of a camera taking a picture from an airplane is vertical at the instant the photo is taken, the principal point of the photograph is the plumb point. However, since the variations in pointing the oblique camera cause corresponding changes in the pointing of the vertical camera, the simultaneous vertical must be corrected for tilt and dip so that the determination of the plumb point location is accurate.

b. The displacement of the plumb point from the principal point in the vertical picture is measured by the tilt and dip of the oblique photograph. To determine the tilt and dip, the plate grid (fig. 170) is placed on the companion gridded oblique so that the vertical and horizontal lines fall on the collimation marks. The angle of tilt is read on the vertical scale opposite the zero vertical angle line. The angle of dip is measured by reading on the fan the angle which the vertical axis of the grid makes with the center line of the oblique grid. After the values of the tilt and dip have been recorded, the plate grid is placed over the vertical taken simultaneously with the oblique, and oriented until the axes of the grid pass through the collimation marks of the vertical. The dip and the difference between the measured angle of tilt and the fixed angle of tilt (angle from the horizontal at which the oblique camera is fixed to point when the airplane is level and stable) are plotted as horizontal and vertical coordinates, respectively; the corrected plumb point location is pricked through to the vertical.

c. If the angle of tilt is greater than the fixed angle of tilt, the tilt correction will be plotted toward the target area, and conversely, if the angle of tilt is smaller than the fixed angle of tilt, the tilt correction will be plotted away from the target area. The angle of dip correction is to the left if the camera is rotated to the left about its own optical axis, and to the right if the camera is rotated to the right.

9. CORRECTIONS FOR MISPLACED MIL GRID.

a. A grid may be placed inaccurately because of errors of technique or because haze or ground forms may make the location of the apparent horizon uncertain. Placing of the grid ordinarily will be performed with sufficient accuracy to reflect little or no error in horizontal angles. However, vertical angles read from a misplaced grid will, in most cases, give unsatisfactory vertical control and will require the application of corrections.

A horizontal plane passes through the lens of the camera at the time an oblique photograph is taken. This plane contains all the points for which the vertical angle is zero, and is materialized on the oblique photograph by the top grid line. When the horizon line is irregular or obscured by fog or dense haze, it is difficult to place the grid properly on the oblique photograph because the position of the horizon line must be estimated. This leads to two types of error: placing the grid too high or too low, and rotating the grid. In effect, this is comparable to tipping the reference plane (zero vertical angle) up or down, and canting it.

b. To establish the slope of the reference plane, resulting from inaccurate placing of the grid, requires three control altitudes. These control altitudes must be altitudes for points of known chart location, spread in a large triangle, and visible in the oblique photograph. From each of these three points, the altitude of the photograph is computed (par. 203). If all three computations give the same result, then the grid was placed correctly. On the other hand, it is more likely that the three computed altitudes will differ noticeably. The reference plane representing these three different altitudes is like the top of a three-legged table, having no two legs of the same length.

c. In figure 175, *E, F,* and *G* are points on the firing chart to be used for control altitudes. From each, the altitude of photo 61 has been computed with the following results: $E = 650$, $F = 638$, and $G = 666$. The horizon of photo 61 was obscured, and it is now obvious that the gridding will necessitate corrections for altitude determinations. The altitude of the photograph determined from *E* is the middle value of the three determined, and may be assigned the title of *effective camera altitude.*

d. On the firing chart, there is some point *H,* between *F* and *G,* from which the altitude of the photograph would be computed as 650 yards, the same as at *E.* Point *H* lies 12/28 of the distance from *F* to *G.* The line *EH* contains all the points from which the altitude of the photograph would be computed as 650 yards, the effective camera altitude. Conversely, the altitude of any point on the line *EH* determined from the effective camera altitude will be true and will require no correction. Line *EH* is, therefore, the *line of zero correction.*

e. The correction applicable to the altitude of any point not on the line of zero correction is proportional to the firing chart distance of the point from the line of zero correction. This proportion is established by points *F* and *G.* If the altitude of *F* is computed, based on the effective camera altitude, a correction of -12 yards must be applied to compensate for the difference between 650 yards and 638 yards. Assume

point F to be 1 inch from the line of zero correction; then the altitude of a point 2 inches away on the F side would be subject to a correction of -24 yards. Therefore, point G must be 1 1/3 inches from the line of zero correction, and on the plus side.

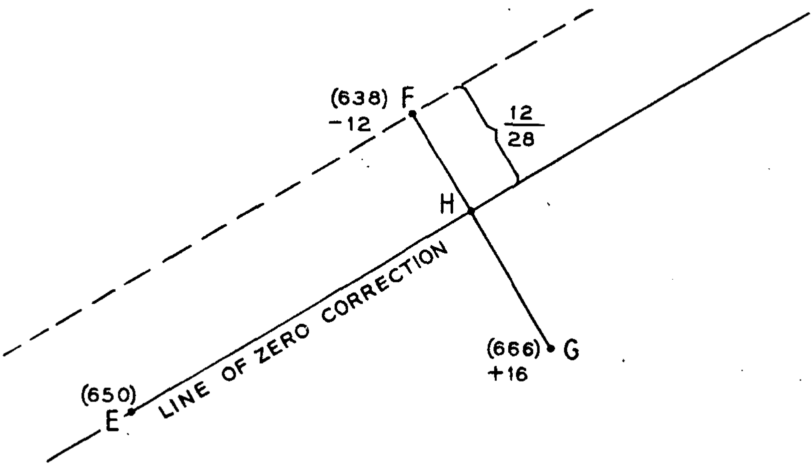


Figure 175. Correcting the altitude when the grid is placed inaccurately.

f. The parallel line graph in figure 176 is a mechanical means of determining corrections. It can be made of tracing cloth or paper. Place the *cross line* of the graph over the line of zero correction. Slide the graph along the line of zero correction until the appropriate correction reading (-12) appears over F. Draw a line on the graph from F through the graph center, and label it *reading line.* Now check the reading line by sliding the graph along the line of zero correction until the reading line falls over point G. If the correction reading is $+16$, as it should be, the graph is ready for use. Slide the graph along the line of zero correction until the reading line falls over a target, then read the correction applicable to that target. The mathematical principle of the parallel line graph is that the reading line, the cross line, and the parallel lines establish a series of similar triangles whose sides are proportional.

The graph should extend far enough to each side of the line of zero correction to cover all points within the area of the photograph used for altitude determinations, and should be divided by enough uniformly spaced parallel lines, each representing 5 yards of correction, to cover the maximum correction of the photograph.

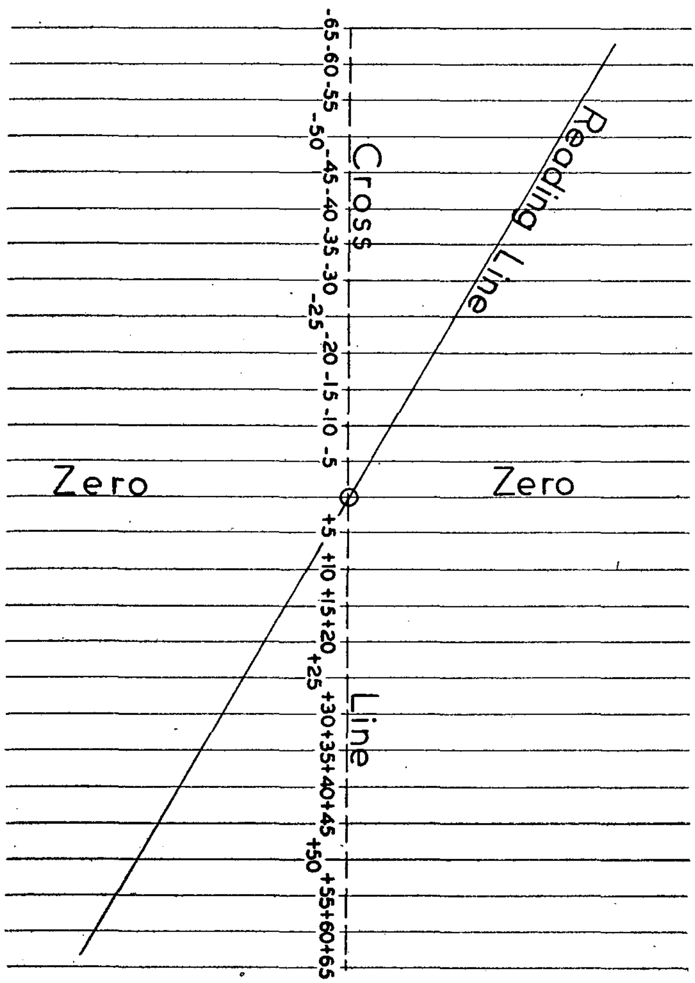


Figure 176. Altitude correction graph for use when grid is placed inaccurately.

APPENDIX VII

This appendix rescinded by Change 2, FM 6-40, 20 February 1947, which will be found at the back of this manual.

APPENDIX VIII
HEAVY ARTILLERY

Section I. GENERAL

1. PRINCIPLES. The principles set forth in the body of this manual apply to all field artillery; some of these principles, however, have such a pronounced effect on heavy artillery that they warrant repetition and emphasis.

The problem of ammunition supply must always be remembered in considering the employment of heavy artillery. Except in an emergency, only those targets appropriate to the caliber and type weapon being used should be attacked by heavy artillery.

The relatively small effects on light artillery of weather, wear and coppering of the tube, and weight of projectile are greatly increased with heavy artillery and must be constantly considered in order to increase the accuracy of fire.

2. WEAR OF TUBE.

a. Wear of tube advances the forcing cone. It is more rapid for higher charges and heavier weapons than it is for lower charges and lighter weapons.

b. In the selection of charges, for a given mission, using personnel must weigh probable error and terminal velocity against wear on the tube.

3. CONDITION OF AMMUNITION. The condition of ammunition affects the wear of the tube and the accuracy of firing.

a. Ammunition should be handled carefully. Rough handling scars the projectile and rotating band. These scars on the projectile increase the wear of the tube and inaccuracies in firing. Likewise, marred rotating bands permit the escape of gas pressure and thus affect the accuracy of firing.

b. Ammunition should be cleaned before loading. Dirty ammunition will increase the wear of the tube.

c. Fuzes should be tight in the projectile.

d. False ogives (8-inch gun only) should be tight on the projectile.

4. RAMMING. The necessity for uniform ramming cannot be overemphasized. Lack of uniform ramming causes variation in muzzle velocity, which results in a large dispersion pattern, thus reducing the accuracy of fire.

5. PROPELLING CHARGE (separate loading ammunition).

a. Propelling charges should be of uniform diameter and without bulges. If bulges are present, the charge should be rolled on a flat dry surface until it is of uniform diameter before it is loaded. The charge should be placed in the chamber so that the igniter pad will rest against the primer tube when the breechblock is closed. Loosely packed powder charges produce erractic muzzle velocities, and should not be fired.

b. When flash reducer strips are used, the section of strip appropriate to the charge is tied smoothly to the outside of the propelling charge increment so that the longitudinal section of the charge and strip are matched for length. The change in muzzle velocity (increase) caused by the use of the flash reducer should be applied in computing range corrections.

6. VARIATIONS IN TRAJECTORY.

a. Weather and rotation of the earth. Changes in weather have a relatively large effect on the trajectory at long ranges. A small change in weather may present a relatively large effect on the trajectory. The necessary corrections for weather and rotation of the earth may be computed from appropriate firing tables.

b. Ammunition and powder lot numbers. Ammunition lots in current use have *VE*s that vary considerably from standard. Where this variation is not known, registration becomes doubly important in order that resulting errors may be corrected. Odd-lot rounds should be used in interdiction and harassing fires and on large area targets. For transfers of fire, the same lot numbers should be used for transfers as were used for registration.

7. CALIBRATION. Calibration of heavy artillery is essential. A *VE* of each piece should be determined. (*Note: VE* of the piece (s) may be checked by regular fire missions if firing with accurate survey data and surveillance of fire is executed.)

The *VE* determined by firing contains the *VE* of the piece and the *VE* of the ammunition being fired. The *VE* of the ammunition (given with each lot number of newer types of ammunition) should not be considered part of the *VE* of the piece. This separate determination of *VE* permits the combining of the *VE* of the piece with the *VE* of the

ammunition to obtain corrections for firing, thus giving more accurate data.

For high velocity weapons (8-inch gun), it is necessary to take into consideration the loss in velocity due to wear during periods between calibrations. This loss in muzzle velocity is applied to the *VE* determined by calibration after a group of equivalent full charges is fired (about 10 rounds).

8. SPECIAL CONSIDERATIONS.

a. The 240-mm howitzer and the 8-inch gun have large minimum ranges inherent in the materiel. This factor must be considered in the selection of positions.

b. The time and effort required to emplace all heavy artillery and the limited amount of traverse necessitate a careful study of the sector to be covered before the pieces are placed in position, to insure that the piece can cover all assigned missions. After the sector has been selected, the center line of the piece (center of traverse) must be emplaced on the center of the sector selected. This may be done by survey (preferably) or by the use of azimuth instruments.

9. ACCURACY OF INITIAL DATA. Due to the problems of ammunition supply and the short life of tubes of heavy artillery, accurate initial data are necessary for reduction of ammunition expenditure. Survey and registration are two of the most important considerations in securing this accuracy.

To insure accurate initial data, the following corrections for basic data should be used: computed range and deflection, corrections for latest metro, corrections for rotation of the earth, and calibration corrections for each piece; or a transfer from a nearby check point on which all of the above corrections were applied. By comparing periodically the range and deflection as measured from the chart for a given check point with the latest adjusted data for that point, corrections are obtained and included in the GFT setting for the expansion or contraction of the deflection fan and firing chart.

10. PRECISION FIRE.

a. Registration. Accurate registration for heavy artillery is vital. Due to lack of long range observation for these weapons, this registration is difficult to obtain. Observation methods most commonly used are as follows:

(1) AIR. This includes organic field artillery air observation and high performance aircraft of the Army Air Forces. (See sec. II below.)

(2) COMBINED OBSERVATION. (Pars. 153–158.)

(3) FLASH AND SOUND RANGING. This method requires coordination with the observation battalions.

b. Destruction. Heavy artillery is particularly effective against fortifications. If more than one piece is used, each is adjusted on the target.

11. DISPERSION OF PIECES. Heavy artillery normally is emplaced on a relatively large frontage and depth. This requires that displacement corrections (width and depth) be made for most fires. In some cases it may be necessary to compute separate data for each piece of the battery (normal with 240-mm howitzer and 8-inch gun).

Section II. ADJUSTMENT OF ARTILLERY FIRE BY HIGH PERFORMANCE AIRCRAFT

12. GENERAL.

a. Necessity. Accurate ground observation often does not completely cover the target area within the range capabilities of heavy artillery. Likewise, artillery liaison aircraft are unable to obtain observation as deep into enemy territory as desired. In order to cover this dead space in observation, the use of high performance aircraft is necessary.

b. Advantages.

(1) DEPTH OF OBSERVATION. The pilot-observer can fly over enemy territory to sufficient depth to observe and adjust long range artillery fires.

(2) POSITION FOR OBSERVATION. A nearly vertical view of the target can be obtained. The pilot is not handicapped by oblique visibility or partially defiladed areas.

(3) ACCURACY OF OBSERVATION. Once the pilot is oriented over the target area, a burst or the center of impact of a volley can be located accurately relative to a target or an agreed point.

c. Disadvantages.

(1) PLANES. Sufficient planes for long range missions are not always available.

(2) COMMUNICATION. Communication between observer plane and ground station is made difficult by the line-of-sight transmission characteristics of the very high frequency (VHF) radio sets used. Weather conditions and enemy radio interference may prevent satisfactory communication.

(3) ENEMY DEFENSES. The enemy may defend certain areas with antiaircraft artillery or strong fighter cover. The aircraft making the adjustment may be shot down or forced to discontinue the mission.

d. Protection. Enemy antiaircraft fire may hinder and slow a mission, but may be neutralized by counterbattery. A more dangerous threat to the success of the mission is interruption by enemy fighters. Since, through radar stations (RDF), enemy fighters may be vectored onto the adjusting plane, the time required for an adjustment must be kept to a minimum. To reduce the danger of surprise by enemy aircraft, the missions are flown by two or more planes, one to adjust fire, the other to weave and observe for hostile aircraft.

e. Source of aircraft. All artillery adjustment missions will be performed by the pilots of the tactical reconnaissance squadrons of the Army Air Forces. Requests for missions are made through army headquarters where they will be processed to the appropriate air unit operating with the army.

13. THE AGREED POINT METHOD.

a. General. The basis of the agreed point method is that every mission is prearranged, in that both the pilot and personnel at the guns know in advance the point at which the opening round will be fired.

b. Agreed point. An *agreed point* is a point marked on a map or a photograph and clearly visible from the air.

(1) Where the position of a target is accurately known and clearly visible from the air, for example, a crossroad, the target itself is the *agreed point.*

(2) Where the position of a target is not accurately known, for example, a hostile battery located by sound ranging, the agreed point is a conspicuous point selected as near as possible to the center of the area where the target is known to be (fig. 178).

c. Prearranged missions. A prearranged mission is one in which both the pilot and the field artillery unit are briefed beforehand with all details regarding the conduct of the mission. The success of the mission depends on:

(1) Accurate briefing.

(2) Accurate observation.

(3) A high standard of training and radio procedure by both air and artillery personnel.

d. Targets of opportunity. This method does not prevent the pilot from shifting fire from the prearranged target to a target of opportunity when the situation warrants. Shifts are made from the target, agreed point, or from reference points arranged for in the briefing.

14. COMMUNICATION.

a. General. Direct communication between the aircraft and the artillery firing is provided by very high frequency (VHF) radio sets. Because of the very high frequency of the carrier wave, the location of the antenna of these sets should be such that a *line-of-sight* electrical path between the plane and the antenna are secured. These radios are made available by the Army Air Forces, which also furnishes the radio operators for the ground set.

b. Control set. The control set is always the set in the aircraft.

c. Location of ground set. The ground set will be located at the battalion fire-direction center of the field artillery organization firing, or at the corps artillery fire-direction center if more than one battalion is to fire.

15. TYPES OF MISSIONS. There are two types of missions that a pilot may be called upon to adjust—precision and bracket.

a. Precision adjustments are made for subsequent transfers of fire when terrestrial observation or observation by organic artillery aircraft is impossible. Precision adjustments are also used for destruction. A center of impact adjustment is a special type of precision mission, and normally should be used to obtain corrections.

b. Bracket adjustments are conducted for counterbattery or on other remunerative targets, such as vehicle concentrations and enemy supply installations.

16. BRIEFING THE PILOTS. As all tactical reconnaissance pilots should be familiar with procedure of artillery adjustment by high performance aircraft, it should not be necessary to brief the pilot concerning procedure. However, pilots (observer and weaver) should be thoroughly briefed in a conference with a ground liaison officer on all points pertinent to their particular mission. In addition, every effort should be made to have the pilots briefed by a representative of the field artillery unit that is to do the firing. The following information should be covered during the briefing:

a. Date and time of the mission.

b. Location of battery positions.

c. Location and description of agreed point (s).

d. Description and location of target (s), type of mission.

(1) LOCATIONS. Locations may be designated by coordinates on a map or marked on a vertical photo. The most accurate location is essential.

(2) PREPARATION OF VERTICAL PHOTO. When the request for a mission has been approved, the army photo interpretation unit is notified and photographs are prepared for the use of the pilots and artillery for each mission.

(*a*) A special rectangular grid approximately to the scale of the photo is superimposed on the negative (during the processing of the print), or may be drawn on the photo at the fire-direction center, with the center of the grid over the target location and the axis indicating the direction of fire. This grid will increase accuracy and facilitate sensings by the pilot. (See fig. 177.) The agreed point is clearly marked on the photos.

Figure 177. Vertical photo showing the agreed point and the rectangular grid with center over target.

(*b*) When the time or facilities are not available for the preparation of such a print, a vertical photo is prepared with concentric circles drawn around the target with radii of 50, 100, and 200 yards. A line is drawn through the target to show the approximate direction of fire.

The agreed point is clearly marked. (See fig. 178.) Instead of concentric circles, a grid may be oriented over the target as an overlay. However, to prevent error from a misplaced grid, a photo prepared in this manner should not be used for center of impact registrations.

Figure 178. Vertical photo showing the agreed point and concentric circles around target.

e. Procedure to be used. (Army)

f. Method of fire, if other than normal.

g. Time of flight; maximum ordinate and slope of fall; projectile to be used, including caliber, type, and fuze; and details for special procedure, such as, time interval between warning and burst (normally 5 seconds), time interval between rounds of a center of impact or of precision in fire for effect (normally 45 seconds to 2 minutes depending on the speed with which the weapon may be served accurately), and fork in hundreds of yards.

h. Location of ground radio stations, call signs and frequencies, "check in" time for mission, air force number of flight mission, and field artillery concentration number.

i. Code time of flight.

j. Known defenses of the enemy.

k. Flight restrictions.

Caution: The airplanes should not leave the ground until the details regarding prearranged missions have been covered fully and are mutually understood. Successful completion of the mission with the minimum hazard to the airplanes depends upon strict adherence to the prearranged time schedule by both the artillery and the airplanes. Shortly after the airplanes take off, radio contact should be established and the artillery should be prepared to fire without delay. It is essential that the artillery adjustment be conducted as rapidly as efficiency will permit whenever our aircraft are subject to enemy air attack or antiaircraft fire. All nonessential time intervals and radio conversation should be eliminated.

17. PROCEDURE.

a. General. Communication is checked in the usual manner. Transmissions between the ground station and the pilot are made using code names and code times. Slightly modified air observation methods are used in adjusting. In the event the pilot designated as observer fails to obtain radio contact and a pilot designated as weaver (for protection) is able to contact the ground, the weaver pilot may take over the mission while the original observer takes over top cover. The artillery will be ready to fire when communication is checked.

b. Precision adjustment.

(1) After identifying the target, the pilot informs the battery that he is ready to observe. The battery in turn reports when ready to fire and gives the code time of flight of the projectile. The pilot commands FIRE. A round is fired on the agreed point or target, the battery notifying the pilot, "On the way." Five seconds before the expected time of impact, "Stand by" is transmitted; at the expected time of impact, "Splash" is transmitted to the pilot. The pilot transmits his sensing to the artillery which again reports when ready to fire. The pilot commands FIRE.

(2) In some instances, due to terrain or weather, it will be difficult or impossible to observe single rounds of HE fired during adjustment. When such is the case, the pilot will request smoke or volleys. The battery will then continue the adjustment using single rounds of smoke, or volleys of HE with converged sheaf.

(3) (*a*) *With a four piece battery.* When the pilot splits a range bracket equivalent to 1 fork and a 50-yard deflection bracket, or considers that the adjustment is sufficiently close, he sends FIRE FOR EFFECT. The battery then fires one volley of HE with a converged sheaf. The pilot senses the volley as a whole. A volley that brackets the target in both range and deflection is sensed *deflection correct, range correct.* If the volley is mixed, it is sensed as *mixed over* or *mixed short* as the case may be. If all rounds are of the same sense, a second volley is fired at the appropriate limit of the 1-fork bracket. An adjusted elevation is computed by the battery or battalion fire-direction center.

(*b*) *With one piece.* Fire for effect is begun when a range bracket equivalent to 1 fork and a 50-yard deflection bracket have been split. The piece fires two rounds of HE at the prearranged time interval. The pilot senses each round. If the rounds bracket the target, two more rounds are fired at the same elevation. If both rounds are of the same sense, two rounds are fired at the appropriate limit of the 1-fork bracket. An adjusted elevation is computed by the battery or battalion fire-direction center from the four rounds fired for effect.

(4) A center of impact adjustment is a special type of precision adjustment. The pilot must be furnished a vertical photograph of the area in which the center of impact will be fired. This photograph should have a grid superimposed to facilitate the accurate location of the burst. An identical photograph is furnished the artillery. After identifying the area, the pilot informs the battery that he is ready to observe. The registering battery fires a preliminary round (usually smoke) in the area where the center of impact is desired. If the burst falls on or near some terrain feature identifiable on the air photo, the pilot requests additional rounds in the same location by sending *fire for effect.* If the pilot desires to move the initial round to a better location, he senses accordingly and then requests the additional rounds; for example, *200 over, fire for effect.* Four additional rounds are fired in succession from one gun, at the time interval arranged in the briefing. The report "On the way" is sent for the first round for effect only. The pilot senses each burst on the grid, or pinpoints the center of impact of the bursts on a photo, if no grid is available. He reports the sensing of each round from the grid, or the photo location of the center of impact when no grid is available, by radio or by other means if necessary. When the speed of the firing unit or absence of enemy interference permits, a center of impact of six rounds may be fired; arrangements for this must be made during the briefing.

c. Bracket adjustment.

(1) Initial procedure is the same as that outlined in subparagraph b (1) above except that the method of fire is by volley.

(2) *Fire for effect* is commanded when a 200-yard range bracket and a 100-yard (or less) deflection bracket are split. After sensing the initial rounds in fire for effect, the pilot is released.

d. One-way procedure. It is possible that in some instances the ground set may be able to receive the aircraft set, but the aircraft will not be able to receive the ground set. If this case does arise, the mission can be performed using one-way procedure. To employ this procedure, the pilot sends "Mabel from Topic—Revert to one-way procedure." The pilot then pauses for 3 minutes and sends "Mabel from Topic—Fire." This 3-minute interval allows the battery sufficient time to issue commands and lay the piece (s). The battery, upon receiving the command FIRE, times the firing so that the round will fall 2 minutes after the command is given by the pilot. The pilot senses the rounds and waits approximately 2 minutes before sending *Fire.* The adjustment is continued with 2-minute intervals between sensings and the pilot's command to fire. All messages transmitted by the pilot are repeated once.

18. INITIAL DATA. Accurate initial data are necessary for an expeditious adjustment of fire. For both precision and bracket adjustments the battery must be laid on the target or on an agreed point in the target area (prearranged during the briefing) with the best available data so that the first round may be fired as soon as the pilot is in position to observe. In bracket adjustment, if the target cannot be accurately located, a small area in which the target can be found is designated. This area should not exceed a 1500-yard square. In the case of hostile batteries, the battery can first be located in a general area by the observation battalion.

19. ILLUSTRATIVE EXAMPLES.

a. Precision, air observation, high performance aircraft.

Target, fortified building; mission, destruction; materiel, 8-inch howitzer, M1; ammunition, HE shell, fuze quick (M51).

Prearrangement: battery is laid on agreed point with map data corrected; code time equals 30 seconds.

The word "Roger" receipts for each message.

PILOT TO GROUND	GROUND TO PILOT	REMARKS
Call sign—Topic	Call sign—Mabel	Pilot arrives over area, identifies agreed point, and reports in
1. Mabel from Topic—I am ready to observe	*2.* Topic from Mabel—Battery is ready; code time, plus 15	Time of flight needed by pilot to allow him to be in position to observe
3. Fire	*4.* On the way *5.* Stand by *6.* Splash	Battery is fired at command of pilot; "Stand by" transmitted 5 seconds before expected time of impact of shell; "Splash" is transmitted at the expected time of impact
7. 200 right, 400 short	*8.* Battery is ready	
9. Fire	*10* On the way *11.* Stand by *12.* Splash	
13. 50 left, 100 over	*14.* Battery is ready	
15. Fire	*16.* On the way *17.* Stand by *18.* Splash	
19. 50 short, fire for effect	*20.* Battery is ready	
21. Fire	*22.* On the way *23.* Stand by *24.* Splash	Battery fires one volley with converged sheaf, fuze delay
25. Mixed over, deflection correct; one target hit	*26.* No further need of you, go home	Volley sensed as a whole; battery or FDC computes adjusted elevation

b. Bracket, air observation, high performance aircraft.

Target, 150-mm gun battery in defiladed position; mission, neutralization; materiel, 155-mm gun, M1; ammunition, HE shell, fuze quick.

Prearrangement: battery is laid with map data corrected on crossroad in vicinity of enemy gun position; code time equals 20 seconds.

The word "Roger" receipts for each message.

PILOT TO GROUND	GROUND TO PILOT	REMARKS
Call sign—Topic	Call sign—Mabel	Pilot arrives over area and searches out target; upon identifying it and prearranged point, he reports in
1. Mabel from Topic—Enemy heavy battery well camouflaged; I am ready to observe	*2.* Topic from Mabel—Battery is ready; code time, plus 15	Time of flight needed by observer to allow him to be in position to observe
3. Fire	*4.* On the way *5.* Stand by *6.* Splash	Battery is fired on prearranged point at command of observer; "Stand by" is transmitted 5 seconds before expected time of impact of shell; "Splash" is transmitted at expected time of impact
7. 400 right, 600 short	*8.* Battery is ready	Observer adjusts fire to target from initial round
9. Fire	*10.* On the way *11.* Stand by *12.* Splash	
13. 200 left, 400 over	*14.* Battery is ready	
15. Fire	*16.* On the way *17.* Stand by *18.* Splash	
19. 50 right, 200 short	*20.* Battery is ready	
21. Fire	*22.* On the way *23.* Stand by *24.* Splash	
25. 100 short, fire for effect	*26.* Battery is ready	
27. Fire	*28.* On the way *29.* Stand by *30.* Splash	
31. Fire effective	*32.* No further need of you, go home	Observer senses first rounds in fire for effect and is then released

c. Precision, air observation, high performance aircraft.

Target, check point; mission, registration; materiel, 240-mm howitzer M1; ammunition, HE shell, fuze quick.

Prearrangement: battery is laid on crossroad located on vertical photo with map data corrected; code time equals 50 seconds; rectangular grid processed on photo used for burst location.

The word "Roger" receipts for each message.

PILOT TO GROUND	GROUND TO PILOT	REMARKS
Call sign—Topic	Call sign—Mabel	Pilot arrives over area, identifies agreed point and reports in
1. Mabel from Topic—I am ready to observe	*2.* Topic from Mabel—Battery is ready; code time, plus 12	Time of flight needed by pilot to allow him to be in position to observe
3. Fire	*4.* On the way *5.* Stand by *6.* Splash	Battery is fired at the command of the pilot; "Stand by" transmitted 5 seconds before expected time of impact; "Splash" is transmitted at the expected time of impact
7. 100 right, 400 short, fire for effect	*8.* Battery is ready	Burst distant from any identifiable terrain feature; sensing places center of impact near road junction in center of grid
9. Fire	*10.* On the way *11.* Stand by *12.* Splash	First round of center of impact fired; "On the way" transmitted for first round only
13. 25 right, 80 over	*14.* Stand by *15.* Splash	Each round sensed as accurately as terrain and the photo grid will permit; rounds fired at 2-minute intervals without command
16. 15 right, 60 over	*17.* Stand by *18.* Splash	
19. 25 right, 40 over	*20.* Stand by *21.* Splash	
22. 35 right, 100 over	*23.* No further need of you, go home	Center of impact at 25 right, 70 over, restituted from gridded photo to firing chart

APPENDIX IX

ABBREVIATIONS; DEFINITION OF TERMS

Section 1. ABBREVIATIONS

The following abbreviations and field artillery terms appear throughout this manual and are necessary for a proper understanding of the subject matter contained herein. Where abbreviations are similar, the meaning will be apparent from the context.

A	Air
A	Firing angle
ADJ	Adjust (command)
Alt	Altitude
AMC	At my command
AP	Aiming point
Az	Azimuth
B	Battery (pieces to fire)
BA	Battery adjust
BD	Base deflection
BL	Battery left
BP	Base point
BP	Base point offset
BR	Battery right
C	Center pair of pieces to fire (command)
c	Change in elevation for 100-yard change in range
Ca	Compass
CF	Cease firing
Ch	Charge
Cl	Close
CL	Center pair of pieces, left piece to fire first (command)
Conc	Concentration
Corr	Correction
CR	Center pair of pieces, right piece to fire first (command)
D	Down
d	The angular deviation (as measured at *OP*) between two bursts, fired with the same deflection, and 100 yards apart in range
DD	Deflection difference

Dev	Deviation
Df	Deflection
DNL	Do not load (command)
El	Elevation
F	Fork
FD	Fuze delay
FDC	Fire-direction center
FFE	Fire for effect
FM	Fire mission
FO	Forward observer
FQ	Fuze quick
FR	Fuze range
G	Graze
G	Piece (preparation of data)
GFT	Graphical firing table
HCO	Horizontal control operator
HE	High Explosive
K	A correction in units per thousand yards of range; ratio of adjusted range to map range
Kr	Corrector
L	Left
LL	Left pair of pieces, left piece to fire first (command)
M	Measured angle
m̸	Mil
MDP	Meteorological datum plane.
Mk	Mark
MF	Method of fire
NCh	Normal charge
O	Observer
OL	Orienting line
OP	Observation post
Op	Open
P	Aiming point
P	Aiming point offset
Proj	Projectile
Q	Quadrant
R	Right (sensings or commands)
R	Range, in thousands of yards, from *G* to *T*
RR	Right pair of pieces, right piece to fire first (command)
r	Distance, in thousands of yards, from *O* to *T*
RCh	Reduced charge
Rd	Round
RGM	Rounds per piece per minute

S	Shift
s	The deflection shift required to keep a burst on the *OT* line when a range change of 100 yards is made
SCh	Supercharge
Sh	Shell
Si	Site
SIC	Survey information center
T	Target
T	Target offset
Ti	Time (fuze setting)
TOT	Time on target
U	Up
VCO	Vertical control operator
VE	Velocity error
VM	Volleys per minute
WA	Will adjust
WP	White phosphorus
Z	Zone

Section II. DEFINITION OF TERMS

adjusted compass. The *Y*-azimuth on which a battery has been laid by adjustment.

adjusted deflection. The deflection on which the base piece has been laid by adjustment (deflection as compared to base deflection).

adjusted elevation. In precision fire, an elevation based on firing, computed to place the center of impact on the target.

adjusted range. Range corresponding to adjusted elevation; range setting, based on firing, computed to place the center of impact on the target.

adjusted time gage line. A pencil line on the indicator of the GFT over the fuze setting for zero height of burst, the hairline being over adjusted elevation.

agreed point. A point marked on a map or photograph, and clearly visible from the air, used in adjustment of fire with high performance aircraft.

air (sensing). An air burst above the level of the base of the target.

altitude. The vertical distance of any point above a selected reference plane, usually mean sea level.

auxiliary base. A line of known distance, used in computing the length of a base.

auxiliary target. A terrain feature whose location relative to a target is known. Surprise fire is placed on the target by adjusting on the auxiliary target, then making the required changes in data to place fire on the target.

base angle. The horizontal clockwise angle from the base line to the orienting line; it is never greater than 3200 mils.

base deflection. The deflection on the sight when the tube is on or parallel to the base line, and the line of sighting is directed on the aiming point.

base line. The line passing through the base piece and the base point; or a line of known direction passing through the base piece, used as an origin for shifts.

base piece. The piece for which data are computed and with reference to which data for other pieces are determined.

base point. A point in the target area whose location is known on the ground or on a firing chart or on both. If its location on the ground is known, it must be readily identifiable and should be in the approximate center of the area, both horizontally and vertically. It often is used as a basis for computing data and as a point of origin for deflection shifts.

basic data. The location of the target relative to the piece in terms of direction, range, and site.

below. An air burst below the level of the base of the target.

burst center. The center of a group of bursts.

burst range. The horizontal distance from origin to point of burst.

cant. The angle between the horizontal and the trunnions of a piece.

center line. A line materialized on the ground representing the center of traverse of a piece. It is used to facilitate emplacement of heavy artillery to avoid subsequent shifting of the trails.

center of impact. The mean point of impact of a group of rounds fired with same piece settings.

check point. A visible point of known location selected as a target for registration; a center of impact; a burst center.

chosen point. A point chosen as origin for a position area survey.

common control. A system of coordinates and altitudes used by more than one unit.

complementary angle of site. A correction to compensate for the error made in assuming rigidity of the trajectory.

concentration. A volume of fire placed on an area within a limited time, or an area designated and numbered for future reference as a possible target.

continuous fire. A succession of salvos, the pieces being fired consecutively at the interval designated in the command.

corrector. The mechanism of a fuze setter, the scale or setting thereon, or the command which results in the corrected time being set on the fuze when the tabular time or fuze range is set on the fuze setter. The amount that the corrector exceeds (is less than) 30 is subtracted from (added to) the tabular value for time.

deflection difference. The amount that pieces are opened or closed to vary the width of sheaf.

deviation. The horizontal angle, measured by an observer, between a burst and the target.

directional traverse. A traverse in which the angles between legs are measured, but distances between stations are not measured.

displacement correction. The correction made for parallax of the aiming posts.

down (command). Decrease site by amount specified. (For navy procedure, decrease in range. See app. VII.)

drill data card. A set of commands and the resultant settings, used to expedite service of the piece drill.

dud. A fired projectile which has failed to burst.

dx. Difference in *X*-coordinates.

dy. Difference in *Y*-coordinates.

factors. Amounts or ratios used in conduct of fire to compute changes in data.

fire capabilities chart. A chart, usually in the form of an overlay, showing the area which can be reached by the bulk of the weapons of a unit.

fire control data sheet. A grid based on higher control, usually on transparent material, on which are plotted the principal points of a series of overlapping vertical photos, and such other control points as may be available.

fixing target location. Establishing the location of a target so that it can be accurately located on a firing chart.

fork. Change in elevation for a change in range of four probable errors.

fuze range. The command or setting in yards which results in the fuze being set for time corresponding to range.

fuze setting. Time; corrector and time; fuze range; corrector and fuze range. In each case the result is a time setting on the fuze.

graphical firing table (GFT). A special rule on which are printed certain ballistic functions. It is particularly useful in the direct determination of corrected elevation. Incidental uses are the determination of factors, and computations.

graze (sensing). In time fire, a burst on impact with the ground or other material object on a level with or below the target.

graze above (sensing). In time fire, a burst on impact above the target. It is doubtful for height of burst.

grazing point. In the determination of dead space, the point where a trajectory will just graze the mask.

high angle fire. Fire in which the quadrant elevation exceeds that for maximum range for the charge. This elevation is approximately 800 mils (45 degrees).

high oblique. An oblique which includes the horizon.

inspection. The determination of the map or photo location of a point by comparison of the terrain with the map or photo detail.

instrument direction. A procedure in which an instrument at the battery is laid on a high air burst, thereby enabling the executive subsequently to check and correct computed or scaled deflection shifts.

instrument reading. The clockwise horizontal angle, vertex at the instrument, from a reference point to the point in question.

jump. The vertical deviation of the initial path of the trajectory from the line of elevation.

laying. Giving the piece the direction and/or elevation (quadrant) commanded.

leg. In a traverse, the straight line between two consecutive stations.

line. In sensing, the observer-target line.

line of fall. The tangent to the trajectory at the level point.

line of impact. The tangent to the trajectory at the point of impact.

line of sighting. The axis of the line of vision of a sight or instrument.

line shot. A burst on the observer-target line.

lost. The sensing for a round which is not seen by the observer.

low oblique. An oblique photo which does not include the horizon.

low order burst. An incomplete detonation.

map K. Proportional correction for discrepancy between scale of a firing chart and that of plotting scale being used.

mask. A terrain feature of such altitude that it restricts fire in the area beyond, resulting in dead space, or limiting the minimum elevation, or both. A terrain feature concealing an installation from hostile ground observation.

maximum ordinate. The difference in altitude between the origin and the highest point of a trajectory.

measured angle. The clockwise horizontal angle (vertex at OP) from target to aiming point; the smaller horizontal angle (vertex at OP) from base point to target.

meteorological datum plane. The altitude of the station preparing the metro message.

metro check point. An arbitrary point in the center of the target area for a particular charge, for which corrections are computed.

metro data. Data to which corrections determined from a metro message have been applied.

metro K. Range correction, in yards per thousand yards, determined from a metro message.

metro message. A tabulation of weather conditions from which the effects of weather on exterior ballistics can be determined.

micrometer. Scale giving the small readings (usually to the mil) of an instrument.

mil. As used in field artillery, a mil is an angle equal to 1/6400 of four right angles. Practically, a mil is the angle subtended by 1 yard at a distance of 1000 yards.

mil relation. The equation: angle in mils equals width of objects in yards divided by distance to object in thousands of yards. It is assumed to be sufficiently accurate for angles of less than 400 mils.

mine action. The action of a shell fuzed for delay which has detonated below the surface of the ground, that is, has failed to ricochet.

minimum elevation. As applied to determination by the executive, the lowest quadrant elevation at which fire will safely clear the mask. As applied to determination by the safety officer, the greater of (1) the minimum elevation as determined by the executive and (2) the elevation consistent with the short limit of the impact area.

mixed (sensing). Applied to a group of bursts with sensings of range or deflection both short and over in unequal numbers. Applied to height of burst in time fire when both airs and grazes result in any proportion.

mosaic. Several overlapping vertical photographs joined together.

muzzle velocity. The velocity of a projectile at the muzzle.

neutralize. To destroy combat efficiency by fire.

observer displacement. The angle *T*; the angle observer-target-piece; target offset.

officer conducting fire. Usually the observer; in massed fires, the gunnery officer of the superior unit.

orientation. A map or other chart is oriented when a line thereon is parallel to the corresponding line on the ground and in the same direction. An angle measuring instrument is oriented when its 0-3200 line is in a known direction.

orienting line. A line of known direction, materialized on the ground, conveniently near the firing battery, to serve as a basis for laying for direction.

over. A sensing indicating that the round is beyond the target or the piece-target line.

percussion fire. Fire with fuzes set to burst on impact.

photo center. The intersection of lines drawn from the collimation marks or from the corners of a photo.

photo K. Proportional correction for discrepancy between scale of a photo and that of plotting scale being used.

place mark. A marked point of known coordinates and altitude, with direction to a known point. A battery place mark usually is in the vicinity of the battery position.

plumb point. The plumb point of an oblique photo is the geographical location of the camera at the instant the picture was taken.

point of burst. For a time fuzed projectile, the point at which the burst takes place, or where it would have taken place if not obstructed by the ground or other object. For a ricochet, the point at which the burst takes place.

point of impact. The point at which the projectile first strikes the ground or other material object.

point designation grid. An arbitrary grid, having no relation to the actual scale or orientation of the chart. For convenience, the spacing of grid lines usually is 1.44 inches, in which case the 1/25,000 plotting scale or coordinate scale can be used for determining and plotting coordinates.

polar coordinates. A system of designating locations by direction from a known line and distance from a known point.

precision fire. Fire the purpose of which is to place the center of impact on the target.

principal point. The center of an air photo.

probable error. A dispersion error as likely to be exceeded as not to be exceeded.

quadrant elevation. The vertical angle from horizontal to line of elevation; the sum of elevation plus site.

range spread. The arbitrarily selected distance between burst centers of the batteries of a battalion firing on a single target, intended to secure deeper coverage of the area. It is expressed in terms of *c*; for example, "½ *c* apart."

refer. To measure, report, and record the deflection to a given aiming point, without changing the plane of fire.

reference point. A point of known location (or direction from another point) generally used as the zero line for instrument reading.

registration. Fire delivered upon a visible point for the purpose of determining corrections.

registration position. A position used only for registration, joined by survey to the combat positions of the unit.

repeat range. In forward or air observation, a request that the previous range be fired again. It does not imply that the range is correct.

restitution. The process of determining the true location of an object the image of which appears distorted or displaced on an air photo. In the field artillery, it is understood to be the process of transferring points from one photo or chart to another.

ricochet. A projectile which bursts above the ground after having struck the ground.

rigidity of the trajectory. The assumption that the trajectory may be tilted up or down through small angles of site without materially affecting its shape.

rule. In lateral conduct of fire, range may be sensed by rule when the deflection error is not more than ½ *s*, or 8 mils. By rule, bursts on the side of the target toward the piece are short in range; those away, over.

safety card. A card issued for a particular battery position for a particular time, prescribing the area into which fire may safely be placed both laterally and in depth.

salvo. A method of fire in which the pieces of a battery fire successively at specified intervals. The interval is 2 seconds unless otherwise specified.

scheduled fires. Prearranged fires which are to be fired at a specified time or upon occurrence of a specified event in the action.

sheaf. The planes of fire of two or more pieces of a battery.

sheaf at. The command to form a regular open sheaf.

shift. The difference in direction between two targets; usually right or left (so much) from base deflection.

short. A sensing indicating that the round is between the observer and the target (or the piece-target line).

simultaneous observation. A means of establishing common direction at two points in which observers at each point zero their instruments on the same celestial body at the same time.

site. The command for the setting on the site scale. Site includes complementary angle of site if the amount is deemed significant. Usually spoken "ESS-EYE."

slope taping. Taping in which slope distance is measured, the slope of the ground is measured, and horizontal distance is computed.

special corrections. Individual corrections for echelonment in depth and differences in altitude, computed at fire-direction center when the nature of the target or its closeness to friendly troops indicates that standing corrections will not be sufficiently accurate.

standing corrections. The algebraic sum of echelonment and calibration corrections in mils and tenths of seconds. These are applied at each piece to the announced site and fuze setting, except when SPECIAL CORRECTIONS is announced, when using method outlined in paragraph 100.

surveillance. Observation of fire for which precise data have been prepared. Fire for effect is delivered without preliminary adjustment, and the observer promptly reports errors of the fire.

survey information center. A place where survey data are collected, correlated, and made available to subordinate units.

target. In sensing, a round which bursts at the target.

target area survey. That portion of battalion survey concerned principally with the location of targets and observation posts.

terrain sensing. A positive sensing of a round not on the *OT* line, based on a knowledge of the terrain near the target.

time. Command or setting which controls the time of burning of a time fuze.

time correction. The difference between adjusted time and the tabular time for the adjusted elevation; the correction applied to tabular time for corrected elevation (site not included).

time fire. Fire in which fuzes are set to act before impact.

time K. Proportional time correction in terms of seconds (usually to hundredths) per thousand yards of range.

time of flight. The time in seconds required for the projectile to travel from the origin to the point of impact or point of burst. The value given in firing tables is the time of flight to the level point.

time on target (TOT). Fire in which the pieces are fired at such a time as to cause the projectiles all to arrive at the target at the same instant.

trajectory. The path described by the center of gravity of a projectile in flight.

transfer limits. Differences in direction and range between check point and target, within which corrections are assumed to be sufficiently accurate for transfers.

transfer of fire. *K*-transfer.

traverse. In survey, a series of consecutive course lines whose relative direction and, usually, whose lengths and vertical angles are determined by measurement on the ground.

up. Increase site by the amount specified. (For navy procedure, increase in range. See app. VII.)

velocity error (VE). The numerical difference between the corrections determined by metro and those determined at approximately the same time by registration expressed in feet per second variation from standard muzzle velocity.

VE-change. The residual discrepancy between metro corrections including any previous *VE* and registration corrections determined at approximately the same time as the metro.

VE correction. The amount of the *VE*, with the opposite sign.

volley. In volley fire, each piece fires the specified number of rounds without any attempt to synchronize with the other pieces.

volleys per minute. Similar to rounds per piece per minute.

wide angle photo. A vertical photo with a relatively wide coverage (70 degrees or greater), having sufficient coverage for use as a firing chart.

zero height of burst. A condition obtained when:

(1) Rounds fired with the same fuze setting and the same quadrant elevation result in an equal number of airs and grazes;

(2) A time bracket of 0.2 second has been split after two airs and two grazes have resulted at the limits of that bracket.

zone. A method of fire, normally used when a single battery is firing on a target, in which five different ranges, usually 50 yards apart, are fired in order to give coverage in depth.

INDEX

TAS, Fort Sill, Okla., (5-15-47—18040)—36852

[redacted]

FIELD MANUAL

FIELD ARTILLERY GUNNERY

CHANGES No. 1 } WAR DEPARTMENT
WASHINGTON 25, D. C., 20 December 1945

FM 6–40, 1 June 1945, is changed as follows:

356. BATTALION.

*　　*　　*　　*　　*　　*　　*

c. S-3.

(1) In addition to * * * fire-direction center. When a target is reported, he notes its location relative to the front lines **or the no-fire lines**, zones of fire, and check points. Acting in accordance * * * of the following:

*　　*　　*　　*　　*　　*　　*

APPENDIX I

SERVICE PRACTICE

*　　*　　*　　*　　*　　*　　*

12. CONDUCT OF SERVICE PRACTICE.

*　　*　　*　　*　　*　　*　　*

b. Except for demonstration, unit service practice should be the continuation of a tactical field exercise which requires that the artillery unit occupy a position and open fire in support of the action of the force it supports. Following the tactical * * * and wasteful procedure. The techniques must be taught and fire discipline must be established by training in the gun park, in the classroom, in nonfiring exercises, and by the use of terrain board, terrain plot, field artillery trainer, and subcaliber attachments. **No officer should fire service ammunition until he is letter-perfect in the sequence of commands and the principles and procedure of conduct of fire. Training must be maintained by continual practice. So-called "match box" firing is a simple and effective method of practice. With a small match box or other object for a target and a pencil to spot the point of burst, any table top can be used for a terrain board. One officer conducts fire; the other acts as instructor and marks the points of burst according to the commands given.** When service ammunition * * * other mechanical devices.

APPENDIX X (Added)

THE VT FUZE

1. GENERAL.

a. The use of this fuze (also referred to as RADIO PROXIMITY), which gives air bursts up to the maximum ranges of the weapons, greatly increases the effectiveness of artillery projectiles. The limitations inherent in the fuze require close coordination and supervision of its use. Therefore, the decision to use VT fuzes, the amount of vertical clearance over friendly troops, the horizontal clearance in front of troops, and flight restrictions for aircraft are *command decisions*.

b. The VT fuze does not replace present standard time fuzes but *supplements* them at the longer ranges of the weapons and in high-angle fire. Present powder train fuzes are most effective to about 15-seconds time of burning. Beyond that point, the advantages of the VT fuze increase while many of the disadvantages are reduced.

2. CHARACTERISTICS.

a. General.

(1) TEMPERATURE. VT fuzes function correctly only when the fuzes are at temperatures from 0° to 120° F. at the time of firing. The atmospheric temperature may be outside this range, but the fuzes must be brought within this range prior to firing. Care should also be taken to avoid loading VT fuzed rounds into hot guns when there are likely to be delays in firing. (See par. 5i.) Overheating of VT fuzes will increase the percentage of duds but does not affect adversely their safety.

(2) WEATHER. Fog, clouds, or darkness have no effect on the functioning of these fuzes. Heavy rain may increase the percent of early bursts along the trajectory when using the E6 type of fuze.

(3) DEPENDABILITY. (*a*) VT fuzes will not function perfectly in all cases. At the present stage of development, between 80 and 90 percent of the present fuzes will operate correctly upon approach within a certain distance of a suitable target. Malfunctioning may occur in the remaining 10 to 20 percent of the fuzes. These malfunctioning fuzes may either:

1. Fail to detonate the shell at any point along the trajectory, or

2. May cause the shell to detonate prematurely at some indeterminate point along the trajectory beyond the arming range. Such detonations constitute a limited hazard to troops under the trajectory beyond the minimum arming range. The small percentage of early bursts along the trajectory over friendly troops and the height of these bursts above the troops will have negligible casualty effect.

(*b*) The fuze in (*a*)*1* above, are duds, and are totally inoperative. The only effect from such duds is the low order detonation which sometimes occurs with any HE projectile upon impact with such hard surfaces as rock, concrete, or metal.

(4) ARMING. (*a*) VT fuzes will not arm for a *minimum* of 2 seconds after they have left the bore. This arming time of flight varies with each weapon and charge. The variations in arming range due to different charges with a given weapon are negligible, resulting in one minimum usable range for each weapon. (See fig. 179.) For later models of fuzes, the minimum arming time is increased to 5 seconds, increasing slightly the minimum usable ranges for light artillery. These ranges are not necessarily safe ranges.

(*b*) If the fuze does not arm, it will become a dud. Once the fuze is armed, it will operate as outlined in (5) below.

WEAPON (Tube)	FUZE	SHELL	PROPER CHARGE	MINIMUM USABLE RANGE (For complete arming) (Yards)
75-mm howitzer M1, M1A1, M2, M3, and M8	T80E6	M48	1*, 2, 3 or 4	1,900**
105-mm howitzer M2, M2A1, and M2A2	T80E6	M1	3*, 4, 5, 6 or 7	2,400**
155-mm howitzer M1 and M1A1	T76E6	M107	5, 6 or 7	4,000
8-inch howitzer M1	T76E6	M106	6 or 7	6,000
240-mm howitzer M1	T76E6	M114	3 or 4	9,000
90-mm gun M1, M1A1, M2 and M3 (For terrestrial fire only)	T80E6	M71	- - -	6,000

* Decreased operational efficiency will result from firing these charges.

** Add 300 yards to these ranges when later model fuzes (E7, E8, E9) are used.

NOTE: Early lots of Fuze T8OE6 cannot be used at Charge 1 (75-mm howitzer) or Charge 3, 4, and 5 (105-mm howitzer).

CHECK THE CARD IN THE FUZE BOX.

Figure 179. Charge and minimum range for use of VT fuze.

(5) ACTIVATION. Fuzes are activated at a predetermined height above the ground which varies with the angle of approach. The height of burst becomes lower as this angle increases. This height has been determined and set in the fuze to obtain the greatest effect against personnel in fox holes or in trenches for all slopes of fall. Firing over water, marshy ground, or wet terrain will increase the height of burst. Light tree foliage and vegetation do not materially affect the height of burst, but dense foliage and thick vegetation will increase the height of burst above the ground by approximately the height of the trees. This effect is decreased at a steep angle of approach, in which case most bursts will occur below treetop level.

b. Capabilities.

(1) Since these fuzes are designed to produce a predetermined height of burst, the adjustment for height of burst is eliminated.

(2) The fuzes (after arming) will function efficiently at any angle of approach.

(3) The height of burst dispersion is independent of the range, and, in general, is considerably less than that of the present time fuzes. The loss in effect due to fuze malfunctions is compensated for by the effectiveness of the height of burst of the remaining rounds.

(4) VT fuzes function to produce air bursts up to the maximum range of the weapon.

(5) Effective air bursts over tanks at all ranges are obtainable.

(6) Errors in vertical control result in errors in range rather than in height of burst.

c. Limitations.

(1) VT fuzes cannot be used at less than the minimum usable ranges as given in figure 179, which precludes their employment in close defense of battery positions.

(2) VT fuzes are usable only with higher charges of each weapon. (See fig. 179.) This limits the minimum ranges at which the fuze can be used with high-angle fire.

(3) Necessary vertical clearance over friendly troops limits firing in close support of these troops to high-angle fire.

(4) Employment of the fuze requires coordination with operations of air OPs.

(5) Lack of an impact element in the fuze results in a small percentage of duds.

(6) The fuze is unusable for ricochet fire, for percussion fire, or for high burst registration.

3. SAFETY PRECAUTIONS.

a. General.

(1) For firing over friendly crests within 2 seconds time of flight,* the minimum elevation is determined in the usual manner: site to mask, plus elevation for mask range, plus 2 forks, plus 5 yards vertical clearance.

(2) When using low-angle fire over friendly crests beyond 2 seconds time of flight, † allowances for vertical clearance are as shown below (fig. 180.)

75-mm howitzer, 90-mm gun . . . . . 50 yards plus 2 forks at crest range
150-mm howitzer . . . . 80 yards plus 2 forks at crest range
155-mm howitzer . . . . 100 yards plus 2 forks at crest range
8-inch howitzer, 240-mm howitzer . . . . . . 150 yards plus 2 forks at crest range

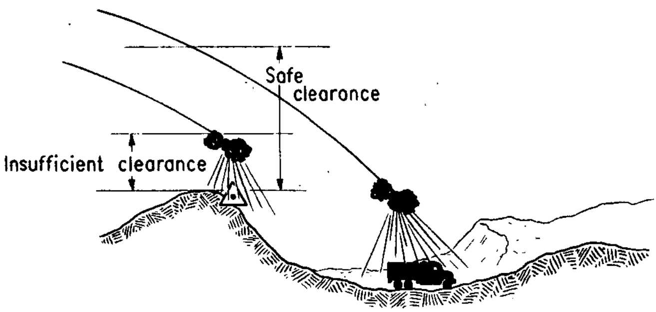


Figure 180. Safe clearance over friendly troops for low-angle fire.

(3) For high-angle fire over friendly troops, the allowances are used as range rather than vertical clearance, to prevent detonation of the fuze by the slope. (See fig. 181.) If the friendly troops are on the same level as the burst, additional range clearance may be necessary.

(4) For firing over hostile crests, an allowance should be made for clearance of 1 fork plus 30 yards for light artillery, and 1 fork plus 50 yards for medium and heavy artillery. This clearance is necessary to prevent wasting rounds on the crest.

(5) If the terrain is marshy or wet, the average height of burst will be higher, and the allowances (in yards) in (2), (3), and (4) above,

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*The safety factor of 2 seconds applies to all charges when the E6 model fuze is used. For later models (E7, E8, E9), the safety factor is 5 seconds.

†The safe unarmed *range* from this 2 seconds is less with a lower charge than with a higher charge.

should be increased 50 percent. For firing over water, the allowances (in yards) should be increased 100 percent.

(6) VT fuzed shells must not be fired close to friendly aircraft. One hundred yards is a safe clearance to prevent detonation.

b. Near crest clearance.

(1) The battery executive will determine and report to the fire-direction center the minimum safe elevation for the visible crest beyond minimum arming range or for safe clearance *at* the minimum arming range, whichever is greater, for the *lowest* usable charge.

Example:

105-mm howitzer, charge 4:

Range to crest, 1,500 yards	El. 100.4
Site to crest	+20.
80 yards clearance	53.
2 forks	8.
Minimum safe elevation for crest	182 mils
Range to minimum arming time, 575 yards	El. 37.0
Site to point 575 yards from piece	+10.
80 yards clearance	139.
2 forks	4.
Minimum elevation at arming range	190 mils

The executive reports, "Minimum elevation, VT fuze, charge 4, 190."

(2) By inspection of the vertical control operator's chart, the S-3 checks other critical crests in friendly territory and determines the minimum safe elevation for clearance of each. If any of these elevations are greater than the elevation reported by the battery executive, the S-3 transmits to the battery executives and computers the corrected minimum elevation; for example "Minimum quadrant elevation for VT fuze, charge 4: Able 198, Baker 180, Charlie 193."

(3) Thereafter, the battery executive is responsible for safety. However, on VT missions handled through fire-direction center, the computers should check the elevation against the minimum VT elevation before transmitting commands.

(4) The S-3 is responsible that any critical crests in friendly territory, other than those immediately in front of the battery position, are cleared. When vertical control is available, this clearance may be readily determined. When firing is conducted from an observed fire chart or photomap with little vertical control, great care must be exercised in determining crest clearance beyond that visible to the executive. High-angle fire and the higher elevations of low-angle fire should be used, when possible, to increase safe clearance over intervening crests.

(5) This procedure may require different minimum safe elevations in different parts of the sector of the fire, for VT coverage of the area.

c. Front line clearance.

(1) Clearance over front line troops is a crest clearance problem and is computed by the S-3 in a manner similar to that in b (1) above, for the charge used.

Examples

150-mm howitzer, charge 4:

Range to front line units, 4,000 yards	El. 307.0
Site to front line units (88 yards above gun)	22.0
80 yards clearance	20.0
Complementary site (for 42.0 mils)	5.0
2 forks	22.0
Minimum safe elevations	376.0 mils

(2) The S-3 must check the minimum safe elevation (maximum elevation for high-angle fire) for all critical crests along the trajectory

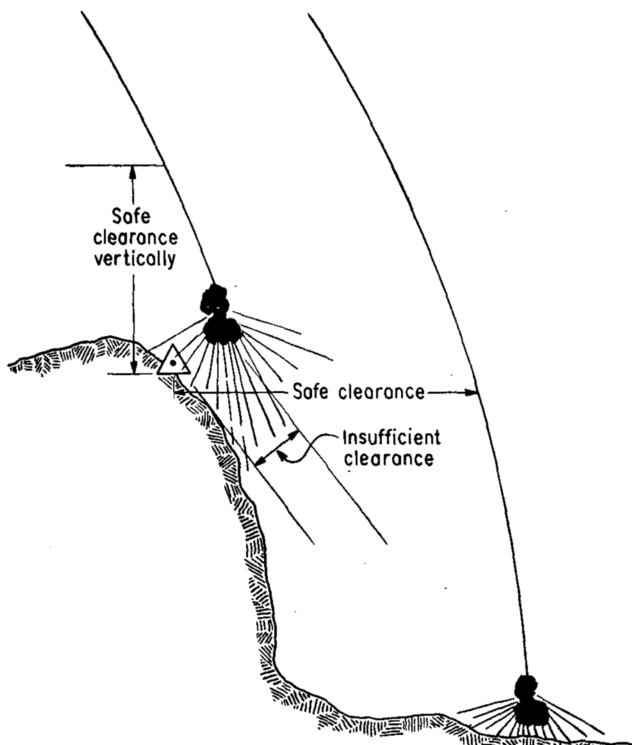

Figure 181. Safe clearance over friendly troops for high-angle fire.

in rear of the front lines. Unless accurate vertical control of friendly terrain is available, the minimum safe elevation cannot be accurately determined and great caution should be used in the employment of low-angle fire. Without vertical control, high-angle fire may be employed, since differences in altitude have little effect. However, the observer must report the location of front line elements nearest the target, both horizontally and vertically, to permit determination of safe clearance of high-angle fire. For example, observer reports: "Base point is 200 right, 50 above, 500 over, enemy patrol, VT, high angle. Nearest friendly element (code word), base point is 300 right, same altitude, 800 over."

105-mm howitzer, charge 4.

Range to friendly elements, 5,000 yards	El. 1,132.4
Site of friendly elements	+20.0
Complementary site	—10.0
80 yards (horizontal)	—10.0
2 forks (horizontal)	—36.0
Maximum safe elevation for minimum range	1,081.0 mils

Data for target:

Range to target, 5,300 yards	El. 1,091
Site to target	+10
Complementary site	—13.6
	1,087.4 mils

Target cannot safely be taken under fire with VT fuze, unless front line elements have cover. Observer is notified of this.

d. Clearance of aircraft.

(1) An armed VT fuze will detonate when it passes within 25 yards of an airplane. An early burst will be dangerous to aircraft within 150 yards for the 105-mm howitzer and at greater distances for larger calibers. When there is considerable firing with this fuze, friendly aircraft may be endangered. Before VT fuze is fired, a radio warning (as prescribed by higher headquarters) is broadcast by the battalion fire direction center. In addition, the battery executives, assisted by designated sentinels at the battery positions, will cause fire to be suspended when friendly aircraft are in or approaching the danger area.

(2) Adjustments of heavy artillery using VT fuze may be conducted with high-performance aircraft provided the pilot is very carefully briefed on his danger area. Briefing must include a safe altitude or safe area over the front lines.

4. OBSERVED FIRES.

a. Adjustment.

(1) When VT fuze is to be used, adjustment is initiated with this fuze. This procedure will permit the initial salvo to be located more easily. Firing is continued with VT fuze as long as terrain conditions permit sensing. If rounds cannot be sensed, a change is made to impact fuze, using the same ammunition lot if possible. When going into fire for effect from an impact adjustment with low-angle fire, the elevation is increased by $12/R$ for 75-mm howitzer, by $15/R$ for 90-mm gun, by $25/R$ for 105-mm howitzer and 155-mm howitzer, and $40/R$ for the 8-inch and 240-mm howitzer. This is necessary to prevent an air burst along the trajectory at the predetermined height, with resultant effect short. In firing over wet or marshy terrain, these factors should be increased 50 percent; over water, 100 percent. These factors are not used for high-angle fire. If a different ammunition lot was used for impact adjustment, a correction for the difference between lots, determined by registration, should be used when fire for effect is begun.

(2) VT fuzes can be used throughout adjustment of high-grade fire, since these bursts are as easily sensed as impact bursts.

(3) The forward observer should include "VT" in his initial sensing when this fuze is desired. The forward observer's sensing of altitude must be accurate, particularly if low-angle fire is to be used. If this fuze cannot be used safely, or if it may be used only at high-angle fire, the observer will be so notified. The forward observer will sense "Percussion" if he cannot sense the VT bursts. The fire-direction center will revert to VT fuze on receipt of the sensing "Fire for Effect."

(4) Adjustment may be made with VT fuze, using bilateral observation to the maximum limits of observation. Long-range adjustments of VT fuze can be conducted by sound ranging, permitting adjustment of air bursts in long-range counterbattery missions without visual observation, previously impossible.

(5) Air adjustment is initiated with VT fuze. Unless visibility, long-range, or difficult observing conditions prevent, adjustment can usually be completed with this fuze. Missions with high-performance aircraft should be fired throughout with VT fuze.

b. Registration.

(1) Registration with VT fuze is unnecessary if an impact registration has been made with an ammunition lot suitable for VT fuzes. If the impact registration was made with ammunition without supplementary charge, registration must be completed with VT fuzed ammunition.

(2) After an impact registration has been completed, VT fuzed ammunition is fired at the same deflection, and range is sensed by rule by

a lateral observer. The VT adjusted elevation is obtained and is stripped of the correction for height of burst, leaving the adjusted elevation which would be obtained with an impact burst and this ammunition lot.

(3) A center of impact registration may be conducted using VT fuze with normal procedure. The site to the mean height of burst is stripped away, leaving the adjusted elevation for percussion fire, which gives a *K* or a graphical firing table setting.

5. FIRE DIRECTION PROCEDURE. The following changes to normal fire-direction procedure are applicable when VT fuzes are to be used.

a. The S-3 is the coordinator of safety in the use of VT fuzes. He verifies that the use of VT fuzes is authorized.

b. He checks safe clearance of friendly terrain before VT fuze is selected for a mission.

c. He notifies the unit pilots and broadcasts the prescribed warning over the radio warning net.

d. In the preparation of initial data for firing VT fuzed ammunition, the vertical control operator includes the correction for height of burst ($12/R$ for 75-mm howitzer, $15/R$ for 90-mm gun, $25/R$ for 105-mm and 155-mm howitzers, $40/R$ for 8-inch and 240-mm howitzers) when low-angle fire is used. No such correction is required for high-grade missions.

e. When adjustment has been completed with impact fuze using a different ammunition lot, the S-3 verifies that the proper correction for the difference in lots is used when data for fire for effect with VT fuzed ammunition are transmitted to the units.

f. To replot a mission fired with VT fuze, using low-angle fire, first the height of burst must be stripped out.

g. The lowest usable charge which will reach the target (allowing for adjustments) should be used with VT fuzes. This procedure will give greater safe clearance and a steeper slope of fall, resulting in more uniform coverage of irregular terrain.

h. VT fuzes should not be used on targets that can be satisfactorily attacked with standard time fuzes.

i. The S-3 should include "Do not load" in his order for *time on target* missions, to prevent the fuze from overheating. The battery executive loads at the proper time to fire the mission. (See par. 78k.)

j. When vertical control is poor (or entirely lacking), as with a photomap or observed fire chart, high-angle fire should be used to reduce the effect of poor control and to increase safe clearance over friendly terrain.

However, high-angle fire is restricted by the minimum range of the usable charges. A method of obtaining a shorter minimum high-angle range, using 105-mm howitzers, is to use charge 3, which will give about 60 percent effective rounds. The decision to use charge 3, with the resulting loss of effectiveness, is a decision of the artillery commander.

6. TACTICAL USE. The VT fuze is suitable for use against targets for which time fire is appropriate. This fuze is suitable for long-range neutralization, harassing, interdiction, and counterbattery missions with air bursts which have not been practicable with standard fuzes. Since the fuze functions at a predetermined height above the ground, it is possible to search irregular reverse slopes by using an elevation giving a steep slope of fall. With high-angle fire, air bursts may be placed near the bottom of deep ravines. Air bursts may be placed over targets at night, in fog, or in any period of poor visibility, following registration. With long-range artillery, adjusted by high-performance aircraft or by the observation battalion, air bursts may be placed over rear assembly areas or command posts. A barrage may be placed over tanks to the maximum range of the weapon, with the bursts following the profile of the ground. If arming range permits, fire against steep slopes may neutralize observation posts, or blast away camouflage to make the targets visible for direct laying weapons. Targets on a ridge line can be attacked more successfully with this fuze than with standard fuzes, due to the fact that the ridge line causes the fuze to function directly overhead.

APPENDIX XI (Added)

Rescinded by Change 2, FM 6-40, 20 February 1947, which will be found at the back of this manual.

[AG 300.7 (11 Dec 45)]

By order of the Secretary of War:

Official:
EDWARD F. WITSELL
Major General
Acting The Adjutant General

DWIGHT D. EISENHOWER
Chief of Staff

Distribution:

AAF (10); AGF (40); ASF (2); AAF Comds (2); Arm & Sv Bd (1); Def Comd (1); Tech Sv (1); except 3, 9 (10); FC (1); BU (1); PG 9 (5); Gen & Sp Sv Sch (10) except 3, 4, 17, 44 (50), 6 (1500); USMA (50); ROTC 4, 6 (1); ASF Tng C 3 (5); RTC 2, 7, 17, 44 (5), 6 (25); A (10); CHQ (10); D (10); B 6 (5); R 6 (5); Bn 6 (50). T/O & E: 2-28 (5); 3-25 (5); 4-155 (50); 7-26 (5); 17-16 (5); 17-25 (5); 17-455 (5); 18-25 (10); 18-35 (10); 44-7 (5); 44-10-1 (5); 44-12 (5); 44-15 (20); 44-115 (20); 44-200-1 (5); Special Distribution.

Refer to FM 21-6 for explanation of distribution formula.

[redacted]

FIELD MANUAL

FIELD ARTILLERY GUNNERY

CHANGES No. 2

WAR DEPARTMENT
Washington 25, D. C., 20 February 1947

FM 6–40, 1 June 1945, is changed as follows:

CONTENTS

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* * * * * * *

40. OPENING FIRE. a. The command to the executive to fire is the command for range or elevation, **or** the command FIRE.

b. The executive's command to the chiefs of section to fire is the command FIRE.

* * * * * * *

42. CEASING FIRE.

* * * * * * *

b. The command SUSPEND **FIRE** is given **by the officer conducting fire when it becomes necessary to interrupt firing prior to end of mission. It indicates that adjustment of fire will continue after a short delay.** If a piece is loaded, the executive reports to the officer conducting fire, "No. 2 (or other piece) loaded." **Firing is resumed at the announcement of range or elevation.**

* * * * * * *

48. FUZE.

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d. Rescinded.

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57. DISTRIBUTION.

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b. For handling irregularities in distribution resulting from the emplacement of pieces in staggered positions, see **FM 6–140.**

* * * * * * *

60. METHODS OF FIRE. Methods of fire are: salvo fire, volley fire, continuous fire, single piece, by piece at my command, fire at will, **ranging rounds,** and zone.

* * * * * * *

67. (Superseded) RANGING ROUNDS. The command to the executive is RANGING ROUNDS. It is followed by two ranges 400 yards apart, or by ELEVATION (QUADRANT) and two elevations 4*c's* (or 4*F's*) apart. The executive has the designated piece fire one round

at each of the ranges or elevations, in the sequence of their announcement. At the command REPEAT RANGING ROUNDS, the same ranges or elevations are fired.

* * * * * * *

78. EXAMPLES OF FIRE COMMANDS.

* * * * * * *

j. (Superseded) Firing ranging rounds; 105-mm howitzer.

(1) Commands:

NO. 2 ADJUST
SHELL HE
CHARGE 4
FUZE QUICK
BASE DEFLECTION
SITE 300
NO. 2, RANGING ROUNDS
ELEVATION 242, 278.

(2) The executive repeats the commands as given, except ELEVATION 242, 278. For these he substitutes ELEVATION 242, FIRE; 278, FIRE.

* * * * * * *

PART THREE (SUPERSEDED)
OBSERVED FIRES

CHAPTER 1
INTRODUCTION; PREPARATION OF DATA

79. OBSERVED FIRES. a. The purpose of conduct of fire is to bring effective fire to the target by adjusting with observed rounds. The fact that the fire has been brought to the target is established when rounds strike the target or when the target has been enclosed by range and deflection brackets of appropriate size. Errors are determined in yards, and corrections in yards are sent to the battery or battalion fire-direction center. The fire-direction center converts these corrections to appropriate fire commands for the pieces.

b. The terminology used herein is employed by ground and air observers in all arms. The use of standard phrases between observers and the fire-direction center facilitates mutual understanding and reduces the volume of communication.

80. PREARRANGEMENT. The artillery observer, ground or air, must keep himself, and where appropriate the organization which he represents, completely informed of the following:

a. The situation (friendly and enemy) within his zone of action and the adjacent zones.

b. The identification, location, and zone of action of the supported unit.

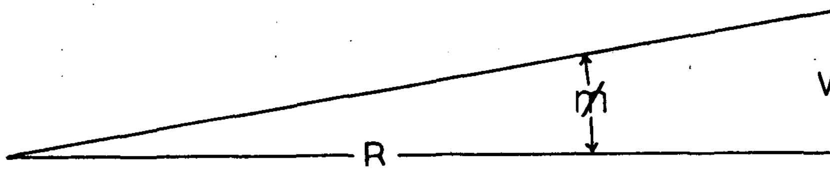
c. The zone of observation.

d. The general locations of batteries.

e. The location and description of the base point, check points, concentrations, known and suspected targets, and any special fires which have been planned within his zone of action and adjacent zones.

f. The maps, photomaps, or photos which are of value to him.

81. THE MIL. The unit of angular measurement used in field artillery is the *mil.* It is 1/6400 part of the circumference of a circle. For practical purposes, a mil is the angle subtended by one yard at a distance of 1000 yards. The *mil relation* (fig. 15) is expressed by $\not{m} = W/R$, where $\not{m}$ is the angular measurement in mils between two points, W is the lateral distance in yards between the points, and R is the mean distance to the points in thousands of yards. The mil relation is approximately true for angles less than 400 mils.



$$\not{m} = \frac{W}{R}$$

Figure 15. The mil relation.

82. DETERMINATION OF DISTANCE. a. Necessity. The observer must be able to determine quickly and accurately the distance between objects, targets, or bursts in order to adjust artillery fire effectively.

b. Estimation of distance. The estimation of distance is facilitated by having a "yardstick" on the ground. This yardstick can be established when ranging rounds (two rounds fired from the same piece and 400 yards apart in range — see paragraph 100) are fired prior to an adjustment, or the observer may establish a known distance in the target area by determining from his map or photo the distance between two points which he can positively identify both on the map and on the ground.

c. Computation of distance. (1) The observer can determine lateral distances by the use of an angle-measuring instrument such as field glasses. To determine the observed deviation (lateral distance) between two objects or bursts, the observer determines from a map or photo, or estimates, the mean distance to the objects. He then measures the angle between them and converts this measurement to yards by use of the mil relation.

Example: Ranging rounds have been fired as ordered by the observer. He desires to determine the deviation in yards between bursts. He

notes the points of impact of the rounds on the ground, and with his field glasses measures the angle between them as 110 mils. He determines from his map that the mean distance of the bursts from his position is 2000 yards. Using the mil relation $m = W/R$ (or $W = m \times R$), he computes the deviation between bursts to be 220 yards (110×2).

(2) When instruments are not available, angles are measured by the hand, fingers, or a ruler held a known distance from the eye. The angle subtended by each is determined by the individual before he goes into the field (fig. 16).

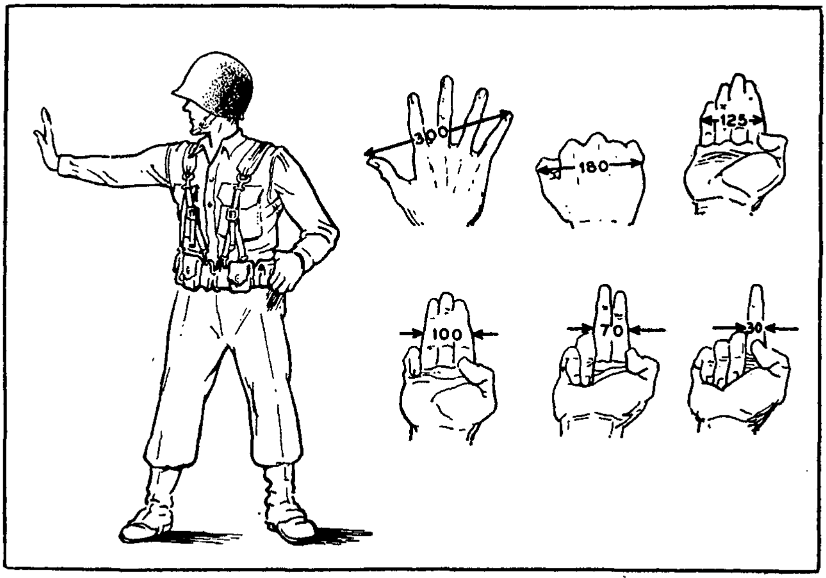


Figure 16. Examples of measuring angles with the hand.

83. PREPARATION OF DATA, GENERAL. a. Normally, the observer designates the location of the target to the fire-direction center by giving the coordinates of the target from a map or photo, or by designating the target with reference to a base point, check point, or other target. The fire-direction center then prepares from a firing chart the initial data for laying the piece. However, at times it may be necessary for the observer to prepare his initial data. When initial data are determined by the observer, he must send them to the fire-direction center in the form of *fire commands* (ch. 2, PART TWO).

b. There are several methods which may be employed by the observer to determine firing data. Some of the "approximate methods" which are most commonly used are discussed in the succeeding paragraphs of this chapter.

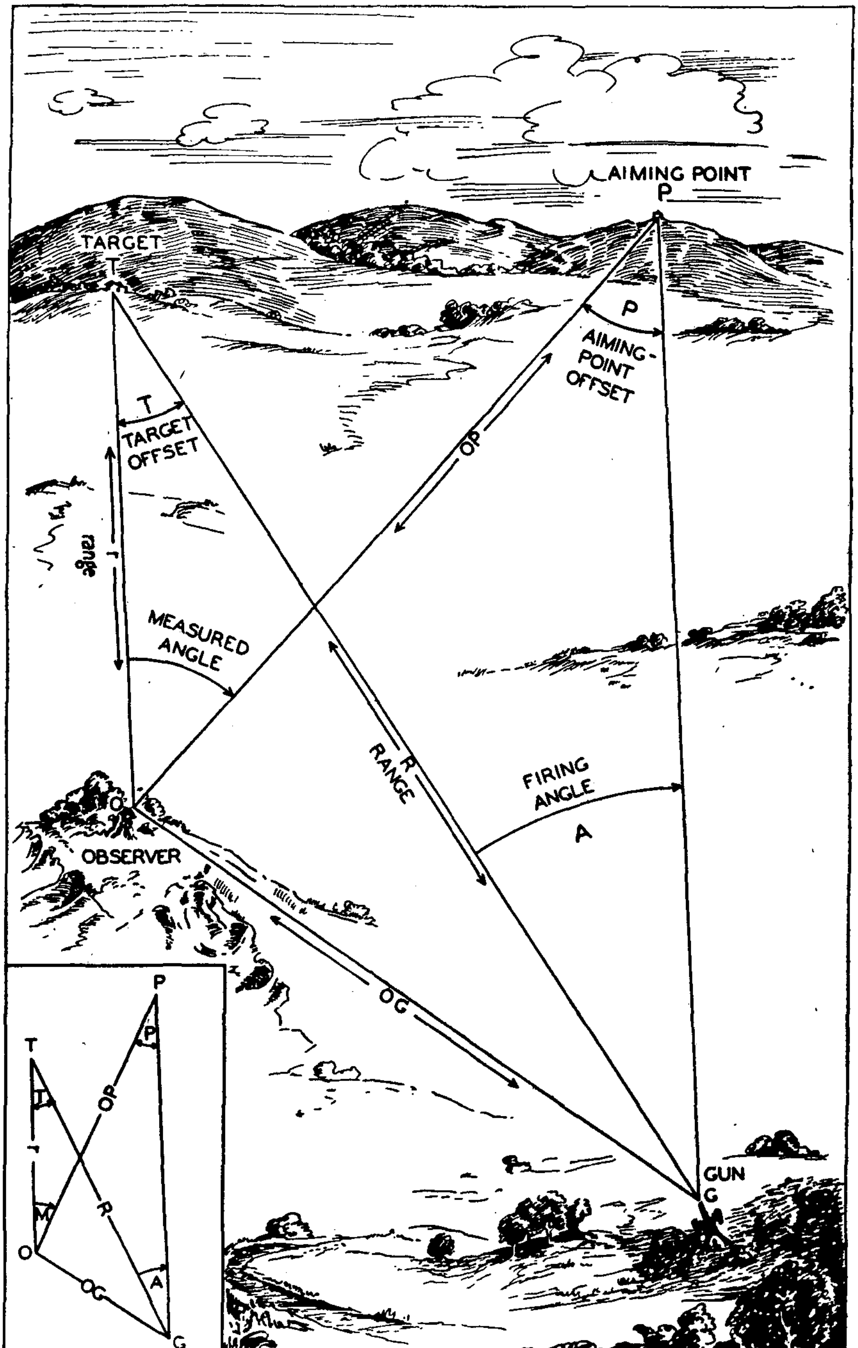


Figure 17. Terms used in preparation of fire.

84. DEFINITIONS AND TERMS. The following definitions and terms are used in preparation of firing data:

a. Direct laying. The piece is laid by sighting on the target.

b. Indirect laying. The piece is laid by sighting on a fixed point or object other than the target. The fixed point or object is called the *aiming point.* Indirect laying is the usual method of laying, because the target generally is not visible from the piece.

c. Firing angle. The firing angle (fig. 17) is the clockwise horizontal angle (vertex at the sight of the piece) from the target to the aiming point.

d. Deflection. The deflection is the setting of the sight which corresponds to the firing angle. When the deflection has been set and the piece traversed to bring the line of sighting to the aiming point, the piece is laid for direction. When the deflection is increased, the line of sighting is moved to the right; and (when the line of sighting is again brought to the aiming point by traversing the piece) the plane of fire is moved to the left. An *increase* of deflection moves the plane of fire to the *left,* a *decrease* moves it to the *right.*

e. Measured angle. The measured angle is the horizontal angle (vertex at the observation post) from the target to an aiming point, base point, or other datum point (fig. 17).

f. Magnetic north. Magnetic north is the north direction as indicated by a magnetic needle swinging freely (without local attraction) in the earth's magnetic field.

g. *Y*-line. The grid lines extending north and south on a map or map substitute are called *Y*-lines.

h. *Y*-north, or grid north. The north direction of a *Y*-line on a map or map substitute is called *Y*-north or grid north.

i. *Y*-azimuth. The *Y*-azimuth of a line is the clockwise angle from *Y*-north to the line. The fire command to indicate the *Y*-azimuth of the direction of fire is COMPASS (SO MUCH).

j. Declination constant. The declination constant of an instrument is the clockwise angle between *Y*-north and magnetic north indicated by that instrument. In other words, it is the *Y*-azimuth of magnetic north. This constant is recorded for any instrument equipped with a magnetic needle; the constant for any one instrument may vary in different localities; in any one locality the constant will vary slightly for different instruments.

k. Target offset. The target offset is the horizontal angle (vertex at the target) between the piece and observation post (fig. 17).

l. Aiming-point offset. The aiming-point offset is the horizontal angle (vertex at the aiming point) between the piece and observation post (fig. 17).

m. Abbreviations and symbols.

M	Measured angle.
A	Firing angle.
T	Target or target offset.
P	Aiming point or aiming-point offset.
BP	Base point or base-point offset.
G	Piece.
O	Observer.
OP	Distance, in thousands of yards, from *O* to *P*.
OG	Distance, in yards, from *O* to *G*.
r	Distance, in thousands of yards, from *O* to *T*.
R	Distance, in thousands of yards, from *G* to *T*.

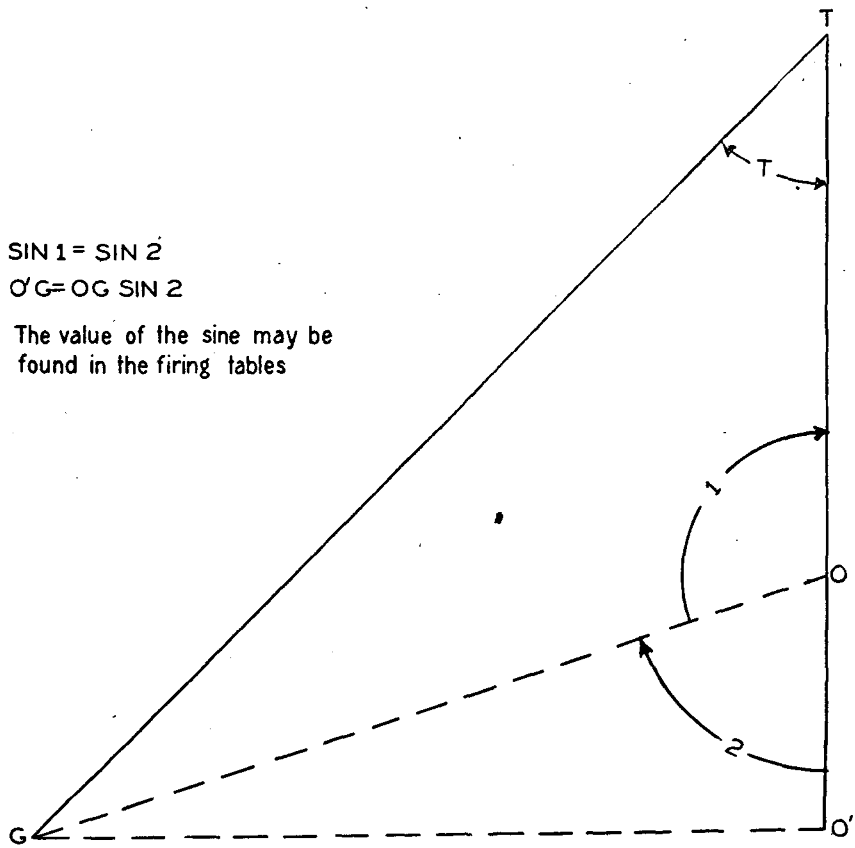


Figure 18. Computing T.

85. COMPUTING *T* AND *P*. The offset T is determined by the mil relation, $T = O'G \div (O'T/1000)$ (figs. 17 and 18). The length of $O'G$ may be determined by multiplying OG by the sine of angle TOG. Offset P (or BP) is determined in a similar manner.

86. COMPUTING DIRECTION BY *Y*-AZIMUTH. To compute the Y-azimuth of GT: measure the Y-azimuth of OT; determine offset T; and apply the T, with the proper sign, to the Y-azimuth of OT. The sign to be used can be learned by a study of figure 19.

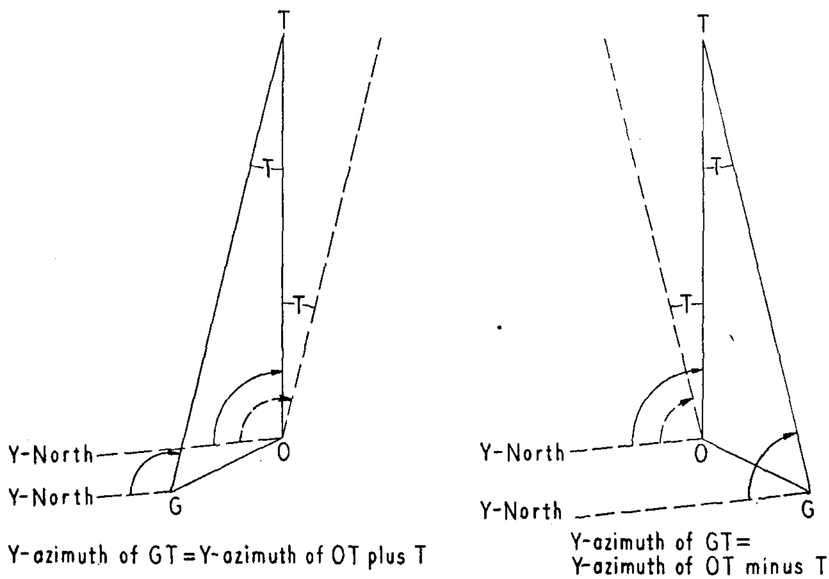


Figure 19. Determining direction by Y-azimuth.

87. COMPUTING DIRECTION WITH DISTANT AIMING POINT. a. To compute A: measure M; compute T and P; and apply the offsets, with proper sign, to M. The signs to be used can be learned by a study of figure 20. A rule of thumb for determining the sign of an offset is as follows: Standing at O, extend an arm toward the target (aiming point). Move the extended arm away from the piece; if the arm moves into (out of) the measured angle the offset is minus (plus).

b. To convert angle A (firing angle) to the deflection command, subtract 3200 if necessary; single angles greater than 3200 cannot be set on the sight of the piece.

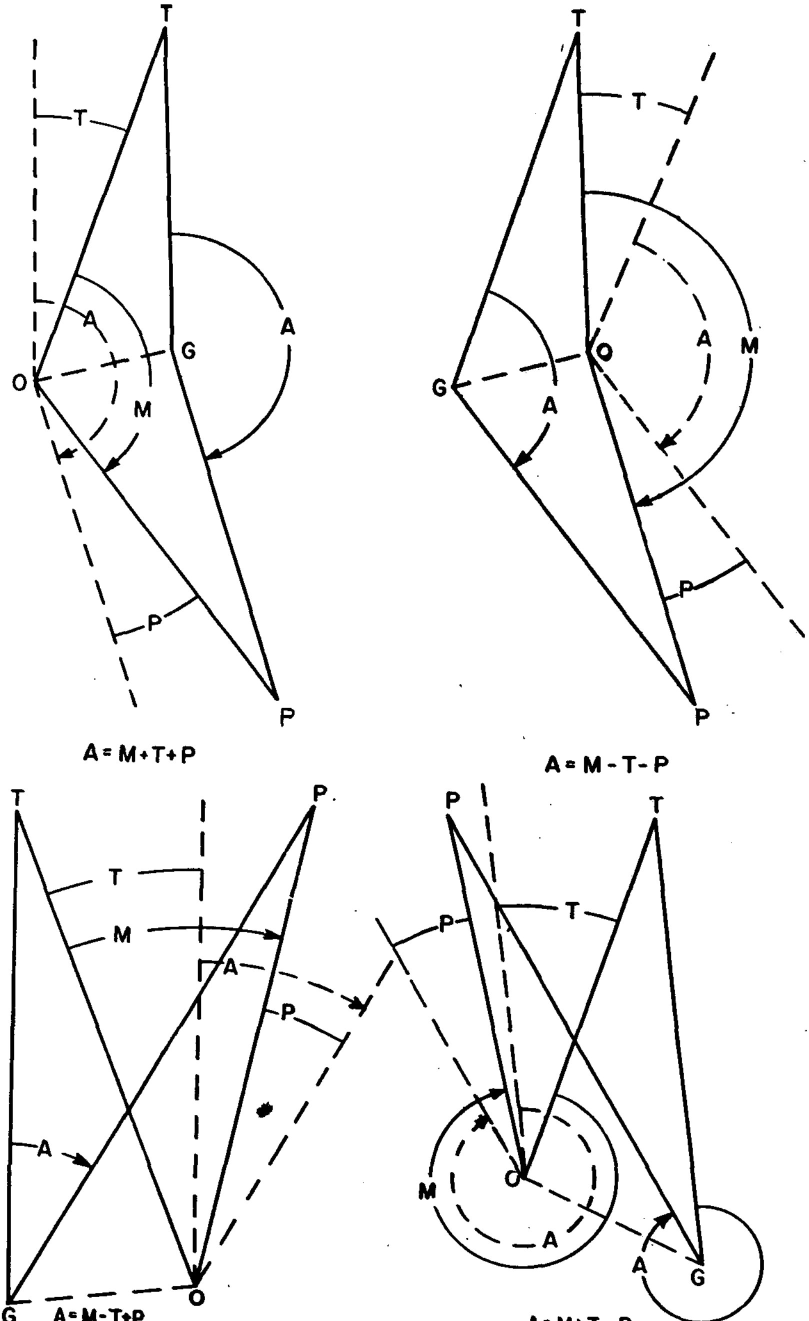


Figure 20. Applying target and aiming point offsets.

88. COMPUTING SHIFTS. a. Using offsets. To compute the shift: measure *M* (fig. 21); compute *BP* (*P* in fig. 21) and *T;* and apply the offsets, with proper sign, to *M*. The signs to be used can be learned by a study of figure 21. In different situations, *M* and the shift may be either right or left, and are not necessarily in the same

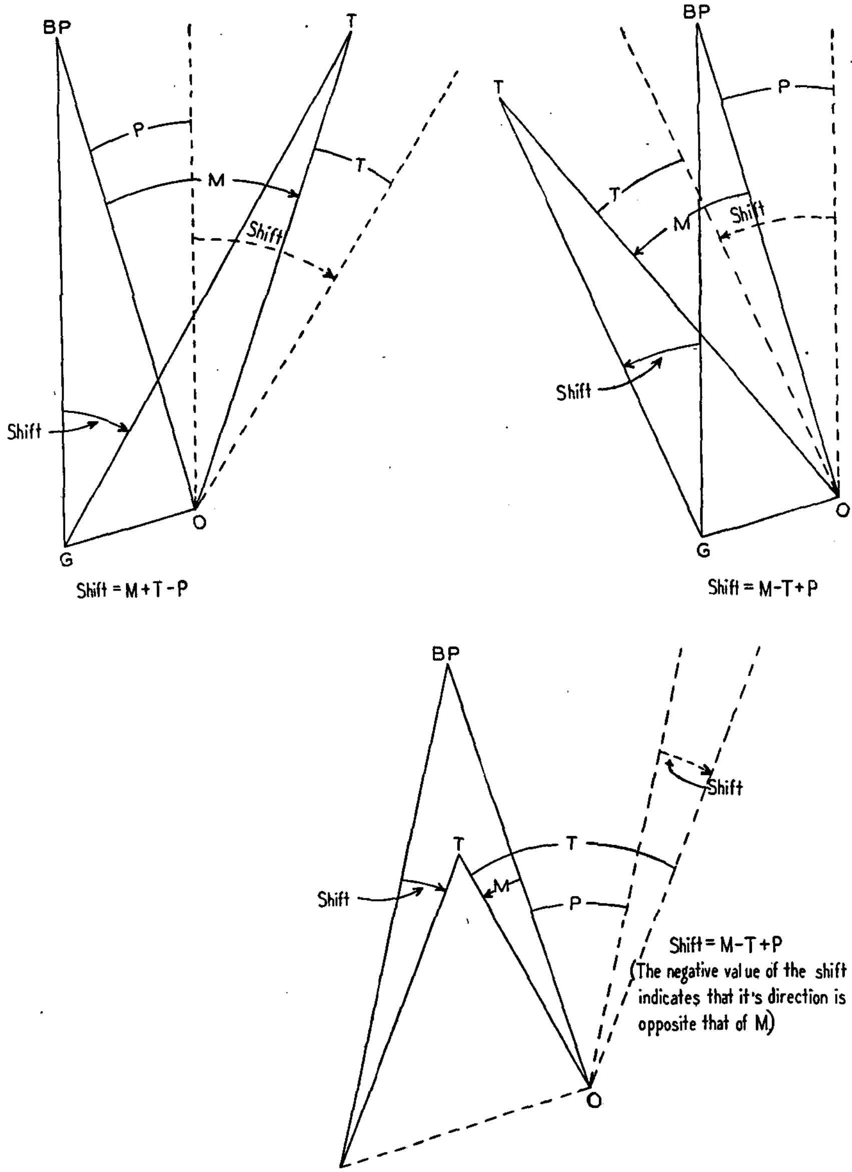


Figure 21. Computing shifts from base point, using offsets.

direction. This method may be applied in determining shifts from one target to another, as well as from base point to target.

b. Using S-shifts. This method requires a knowledge of range-bracketing procedure (ch. 3). Consider *BP* to be the last burst fired. Compute the shift in yards necessary to bring the burst to the *OT* line, and apply one *S* in the proper direction for each 100-yard difference between base-point and target ranges. The result is the shift in yards.

89. RAPID PLOTTING. a. General. When offsets are so large that the mil relation formula is not sufficiently accurate, measured and estimated data may be plotted to scale and the resulting direction and range may be scaled.

b. Diagram. A diagram may be drawn to scale (fig. 22). If the locations of targets and guns are identifiable on a suitable map, necessary lines may be drawn and deflection or azimuth read directly.

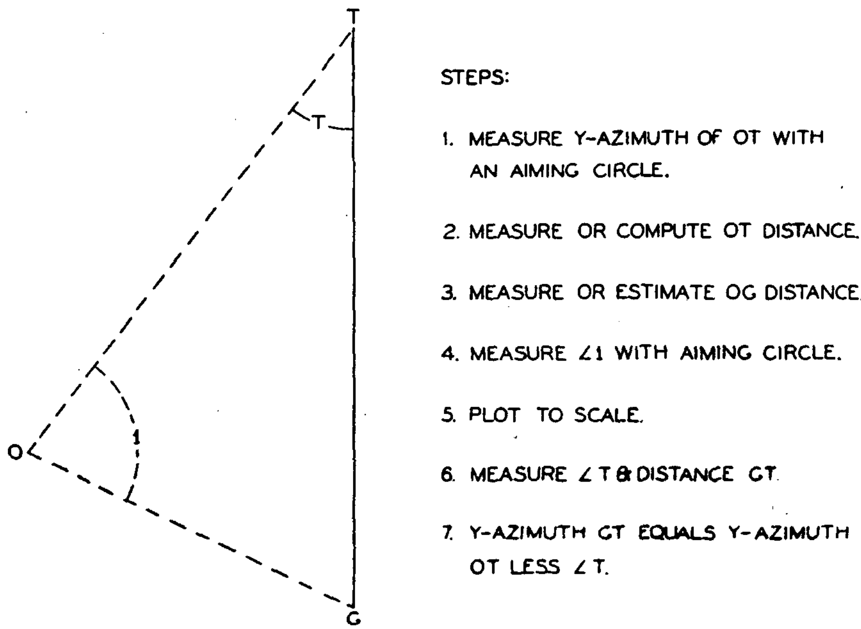


Figure 22. Diagram for method of determining data by rapid plotting.

90. DISTRIBUTION. a. Definitions. (1) A *sheaf* consists of the planes of fire of two or more pieces.

(2) A *parallel sheaf* is one in which the planes of fire are parallel.

(3) A *regular sheaf* is one in which the bursts are approximately on a line and are equally spaced laterally.

(4) The *width of sheaf* is the lateral interval between flank bursts.

(5) An *open sheaf* is one covering the maximum front without shifting. The prescribed widths of open sheaf for the various calibers, and the front covered by an open sheaf, are as follows:

Caliber	*Width (in yards) of open sheaf*		*Front (in yards) covered by open sheaf*	
	4-piece Btry	*6-piece Btry*	*4-piece Btry*	*6-piece Btry*
75-mm	100	100	130	130
105-mm	100	150	150	200
155-mm	200	250	260	310
8-inch	300		380	

(6) The *front* covered by any sheaf is the width of sheaf plus the effective width of a burst.

b. Parallel sheaf. (1) The battery executive forms a parallel sheaf (fig. 23). Immediately upon occupation of position, he lays the battery parallel with an aiming circle or other instrument on the indicated base angle or compass. The detailed operations for forming a parallel sheaf are given in FM 6–140.

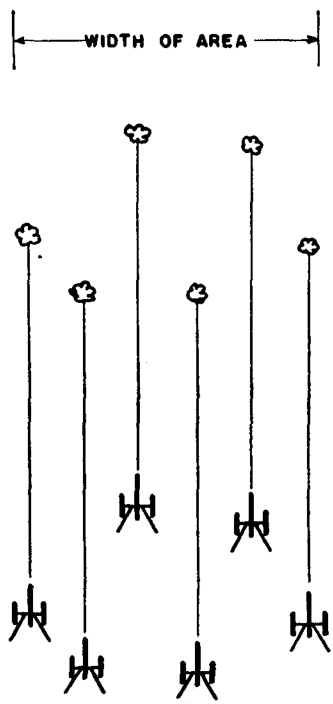


Figure 23. Parallel sheaf.

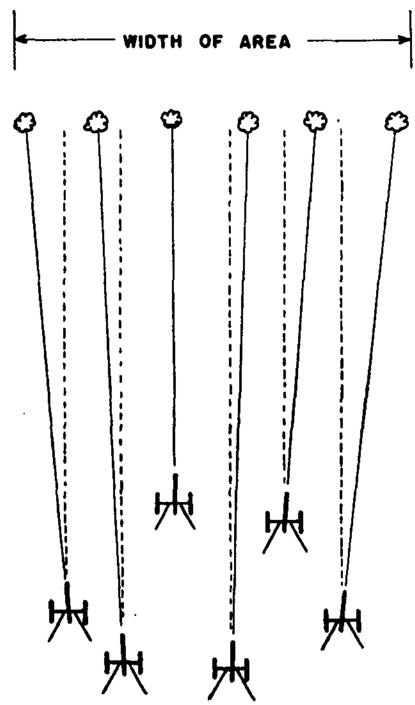


Figure 24. Individual corrections to form a regular sheaf.

(2) In most cases, a parallel sheaf is sufficiently accurate and effective. This is particularly true with massed fires and fires well beyond our troops.

c. Regular sheaf. (1) There will be occasions when the pieces of a battery are so irregularly placed both laterally and in depth that individual corrections for lateral distribution and variations in range are necessary to provide more effective fire on targets close to our own troops, on accurately located targets, on point targets, and on barrages.

(2) When this is the case, the observer (or the fire-direction center) orders SPECIAL CORRECTIONS. The executive must be prepared to form a regular sheaf, with the bursts approximately on a line, of whatever width and at whatever range the observer or the fire-direction center may designate (figs. 24 and 25).

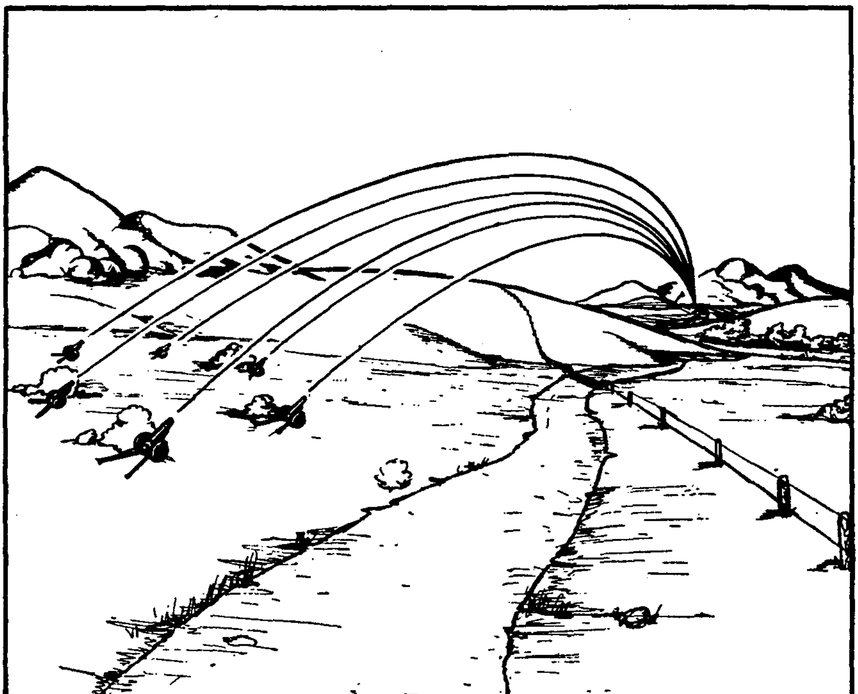


Figure 25. Result of range and distribution corrections on a point target.

91. ANGLE OF SITE. a. The accurate determination of angle of site is important, particularly if the fire of additional batteries or battalions is to be superimposed on the adjustment of one battery. Normally, the observer sends to the fire-direction center the difference in altitude between the target and a known point, and the fire-direction center computes the angle of site.

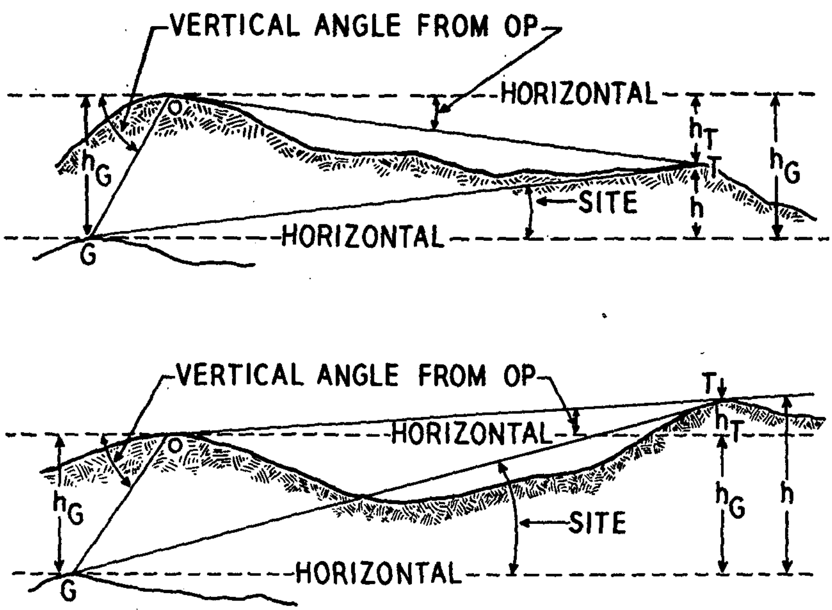
b. To compute site with an instrument at the observation post (fig. 26):

(1) Measure the angles of site to the target and to the piece.

(2) By the mil relation formula, compute the amount in yards that each is above or below the observation post.

(3) Compute the amount in yards that the target is above or below the piece and divide that amount by *R*. The quotient is the angle of site in mils.

(4) The angle of site is *plus* if the target is above the piece, *minus* if below.



h = difference in altitude between gun and target
h_G = difference in altitude between observer and gun
h_T = difference in altitude between observer and target

Figure 26. Computation of site.

c. To compute angle of site with a chart: determine altitudes of target and piece by interpolation between contours or known altitudes; then proceed as in b (3) and (4) above.

d. The initial angle of site in time area fire is the computed angle of site, plus such amount as will insure air bursts.

e. The setting for zero site is 300. The setting for a site of +10 mils is, for example, 310; for a site of —5, 295.

f. For use of site in applying elevation corrections for calibration, and for echelonment of pieces in depth, see FM 6–140.

92. HEIGHT OF BURST. a. The height of burst may be varied by changing the *time of burning* (fuze setting) or by changing the *site*. A change in the time of burning moves the point of burst along the trajectory, which changes the range of the burst as well as the height of the burst (fig. 27). A change in the site, on the other hand, raises or lowers the burst in a vertical plane through the target (fig. 28).

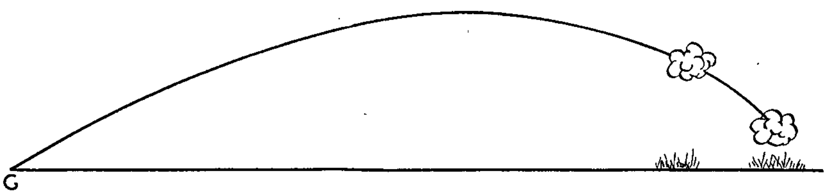


Figure 27. Changing the height of burst by changing the time of burning (fuze setting).

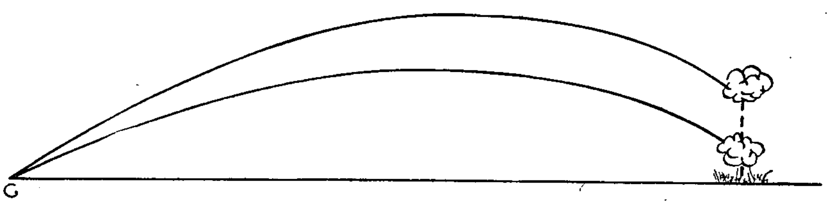


Figure 28. Changing the height of burst by changing the angle of site.

b. Before employing time fire, the time of burning is adjusted by a time registration to give a zero height of burst; i.e., one which gives a mean height of burst at the surface of the ground. Thereafter, the fire-direction center accompanies each range change with a corresponding time of burning, and the observer controls the height of burst entirely by site changes. *For a discussion of the VT fuze and its employment—see appendix X, change 1, FM 6-40.*

CHAPTER 2
GENERAL PRINCIPLES OF CONDUCT OF FIRE

93. ELEMENTS TO BE ADJUSTED. In conduct of fire the observer adjusts the following elements, based upon positive sensings obtained from observed rounds.

a. *Direction,* to cause the mean line of fire to pass through the target.

b. *Distribution,* to cause the sheaf to cover the desired front.

c. *Site,* in time area fire, to cause the projectiles to burst at the proper height above the ground (20 yards for light and medium artillery).

d. *Fuze setting,* in time registration, to secure a zero height of burst.

e. *Range,* to cause the projectiles to strike or burst at the most effective range.

94. APPEARANCE OF BURSTS (fig. 29). a. HE shell, quick fuze. The black smoke is discolored by dirt, and spreads both upward and laterally.

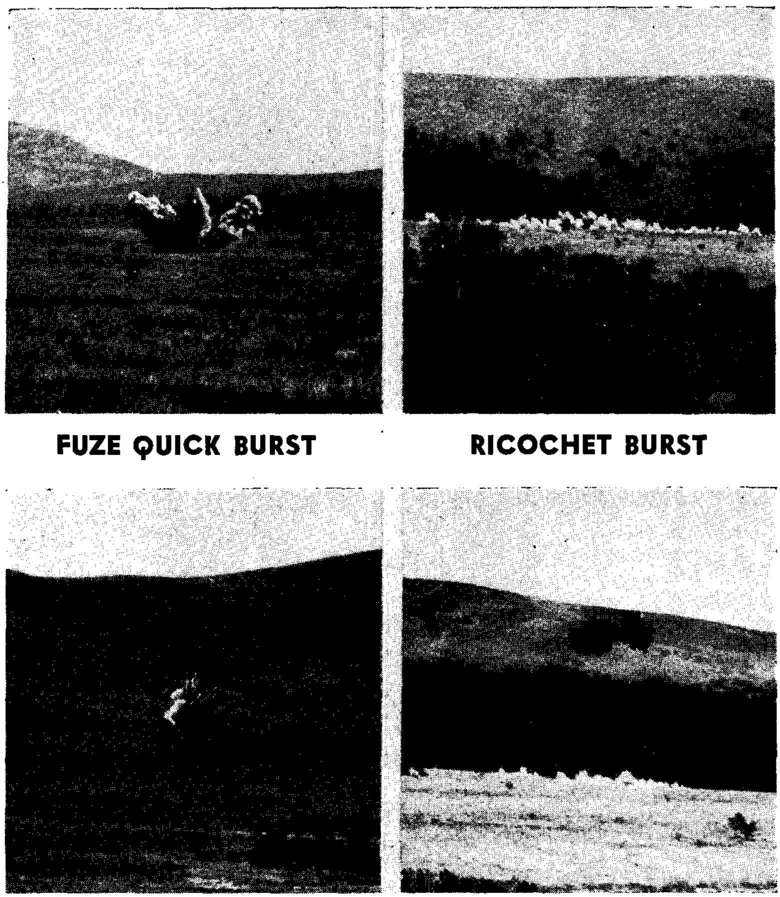
b. HE shell, mine action. A mine action burst usually sends up a vertical column of dirt, often with clods of earth, and with very little smoke. The explosion is muffled.

c. HE shell, ricochet. A ricochet burst is characterized by a flash, sharp explosion, and a ball of black smoke above dust kicked up by fragments. The pattern of the side and base spray is very noticeable. When delay fuze is used, ricochets are most easily identified by the absence of characteristics of mine action.

d. HE shell, air burst. The burst is characterized by a flash, sharp explosion, and a ball of black smoke which becomes elongated along the trajectory. The effect of fragments can be seen below the burst, if the burst is not too high. The effect of nose fragments usually can be seen in prolongation of the trajectory.

e. Smoke shell. (1) *White phosphorus* burns rapidly, and at once forms white smoke which tends to rise because of the heat generated by the burning phosphorus.

(2) *Base ejection smoke,* bursting in air, emits smoke canisters which can be seen following the approximate path of the trajectory. Smoke



FUZE QUICK BURST | **RICOCHET BURST**

MINE ACTION BURST | **AIR BURST**

Figure 29. Appearance of bursts.

is emitted from each canister from three to four minutes, forming a dense, low-lying screen.

95. SENSINGS. a. Range (fig. 30). A burst which is beyond the target from the gun is sensed *over* for range; one which is between the target and the gun is sensed *short* for range. A round which strikes the target is sensed *target;* one which is at the proper range, but is off the target for deflection, is sensed *range correct.* Range is sensed *doubtful* if no positive sensing was obtained, or *lost* if the burst was not observed. In time area fire, a burst on impact between piece and target is sensed *doubtful* for range, since an error in site, rather than range, may have caused the round to strike short of the target; however, if

the burst is so short that it is evident that range is in error, it is sensed *short* for range. In area fire, when in the same volley (salvo), rounds are both *short* and *over,* the sensing is *bracketing* for range.

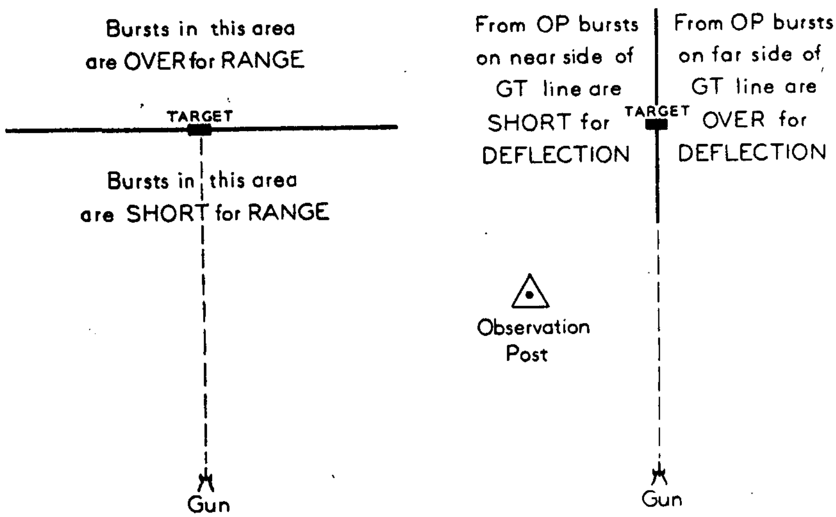


Figure 30. Areas of overs and shorts in range and deflection.

b. Deflection (fig. 30). A burst which is on the far side of the gun-target (*GT*) line from the observer is sensed *deflection over;* one which is on the observer's side of the *GT* line is sensed *deflection short.* Deflection is sensed *deflection doubtful* if no positive sensing was obtained. Under certain conditions, described later in paragraph 110c, deflection may be sensed *deflection correct.*

c. Time fire. A burst in the air is sensed *air;* a burst on impact is sensed *graze.* In volley fire, if both *air* and *graze* bursts are obtained in the same volley, the sensing is *mixed* when equal numbers of *airs* and *grazes* are obtained, or *mixed air* (*mixed graze*) when a preponderance of *airs* (*grazes*) is obtained.

d. VT-fuzed shell. When the burst is low, it can be sensed on the ball of smoke in the same manner as an impact burst. When the burst is high, sensing must be made on the effect (dust kicked up by fragments). The observer must make certain that he bases his sensings on the *center* of the effect pattern, and not on stray fragments at the edge of the effect pattern. When the fuze fails to function, the round will result in a dud, and the observer can often see where the projectile strikes the ground by the dirt it kicks up on impact. In low-angle fire, a range sensing of *over* based upon the point of impact of a dud must

be accepted with caution, since the normal point of burst of such a round would be at a considerably shorter range.

e. Ricochet fire. Fuze action is sensed in ricochet fire as *ricochet* or *mine action.*

f. Doubtful and lost. A burst should not be sensed positively unless the observer is certain that the sensing is correct. A sensing of *lost over* (*lost short*) may be made when there is accurate knowledge of the terrain, and the deflection is known to be reasonably correct. After a sensing of *lost,* a bold change is made in the direction most likely to give a visible burst. The first round from a cold piece may be erratic; if such a round has been sensed positively and later becomes one limit of the range bracket for fire for effect, the sensing is considered doubtful, and another round is fired at the same range to verify the previous sensing.

g. Positive sensings. One positive sensing is sufficient to establish a limit of a bracket. Sensings must be made promptly, except when it is necessary to take advantage of drifting smoke. Sensings must be based on what the observer sees while it is before his eyes, not on what he recollects. Except for terrain sensings, range or deflection sensings on bursts wide from the target should be made with caution. When sensings are made on drifting smoke or on shadows, the direction of the wind and the position of the sun must be considered.

96. TYPES OF FIRE. a. Precision fire. Precision fire is used for registration, attack of point targets, and destruction. It is used against stationary objects. Since destruction requires a large expenditure of ammunition, every round is fired with the most exact data available. Light artillery is effective against light structures only. More than one piece may be used on a target; each is adjusted separately. Precision fire must be *accurate* but must be conducted *expeditiously.*

b. Area fire. (1) Area fire is used against personnel and materiel capable of movement or dispersed in an area, and unsuitable as targets for direct laying. It may be used for a rapid and approximate registration. Adjustment of area fire must be accurate, particularly if fires are to be massed using the data determined from the adjustment. The adjustment should be as rapid as is consistent with accuracy in order to insure fire for effect before the enemy can escape or take cover. Fire for effect must be accurate and dense; ineffective ranges are eliminated.

(2) Normally, fire is opened with platoon volleys, but may be with battery volleys to insure early sensings, or with a single piece to save ammunition. Salvo fire may be ordered if desired; adjustment of de-

flection in deflection-bracketing is facilitated by use of salvos rather than volleys. In time fire, more than one piece should be used. Adjustment is with a parallel sheaf unless otherwise designated by the observer.

(3) In area fire, the observer must select a well-defined point upon which to adjust. This "adjusting point" may be a distinctive terrain feature, or it may be some portion of the target, such as a truck or tank. The observer selects an adjusting point at or near the center of the area upon which he wishes to place fire. For surprise fire, he may select some nearby point (auxiliary target), adjust on it, and then shift the fire to the area which includes his target.

97. ADJUSTMENT. Based upon positive sensings, the elements in error are adjusted to bring effective fire to the target. Positive sensings are most readily obtained when bursts are on the *OT* line. *The basic procedure during adjustment is, first, to bring bursts to the OT line, and then to keep bursts on the OT line during changes incident to the adjustment.*

98. BRACKETING THE TARGET. Fire is adjusted on the target by *bracketing* the target for both range and deflection and then splitting these brackets to the degrees prescribed in the following chapters. It is better to overestimate the necessary corrections than to underestimate them because in this way a bracket is more readily obtained. The *controlling element* is that element (either range or deflection) which is more difficult to sense. Range is the controlling element and *range-bracketing* procedure is employed when the observer is on or near the gun-target (*GT*) line (target offset of 500 mils or less). Deflection is the controlling element and *deflection-bracketing* procedure is used when the observer is considerably to one side of the *GT* line (target offset greater than 500 mils). Normally, the observer employs ranging rounds (par. 100) to determine which of these methods is to be employed in attacking a particular target.

99. KEEPING BURSTS ON THE LINE. a. If a range change is made from a line shot, a corresponding deflection change is necessary to keep the burst on the *OT* line; conversely, if a deflection change is made from a line shot, a corresponding range change is required. *S* is the deflection shift in yards which keeps the burst on the *OT* line when the range is changed 100 yards (fig. 31). For example, a deflection shift of 1 *S* is made in the proper direction for each 100-yard change in range; a range change of 100 yards is made in the proper direction for each deflection shift of 1 *S*.

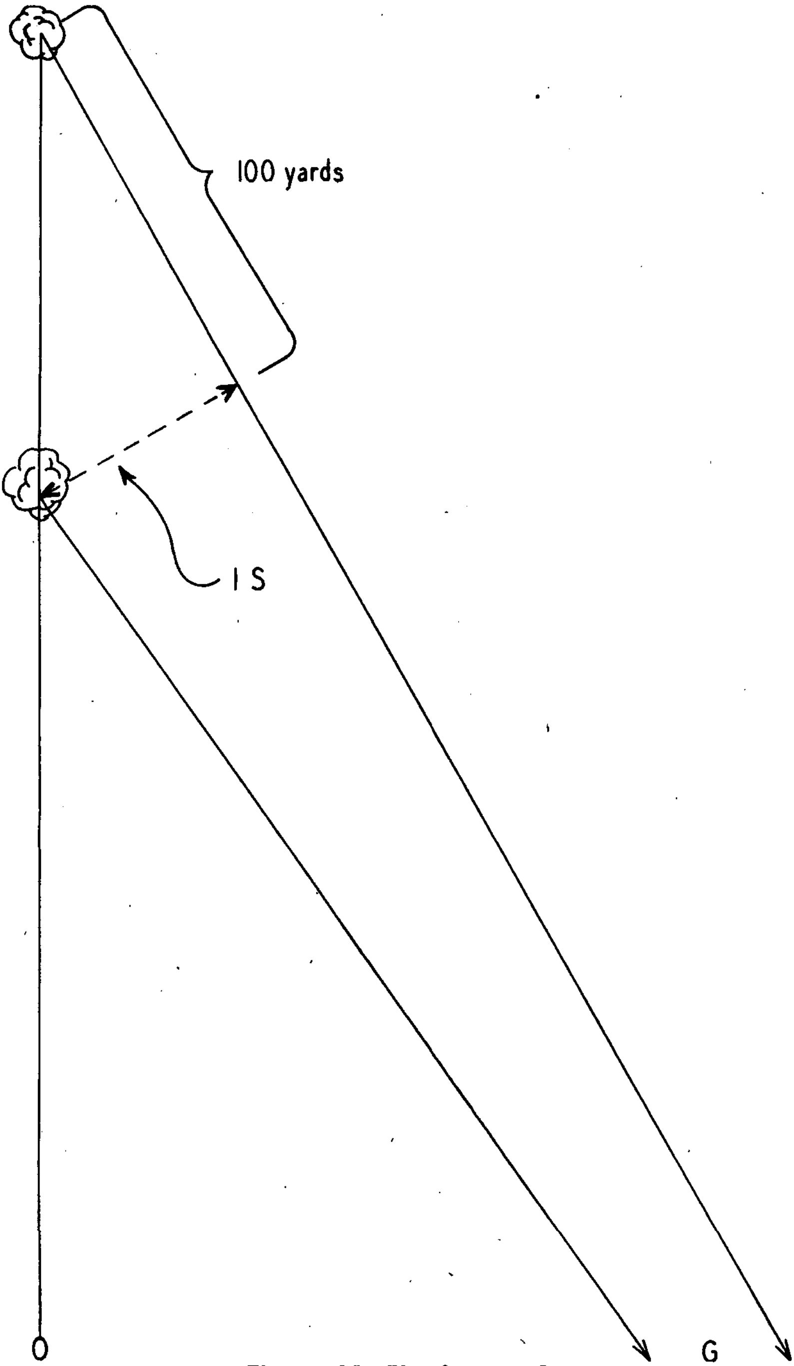


Figure 31. The factor, S.

b. When sensings are obtained, small deviations which might be caused by dispersion or by minor irregularities of the ground are ignored. Larger deviations which might hamper future sensings are corrected to place shots on the *OT* line.

100. RANGING ROUNDS. a. *Ranging rounds* consist of two rounds fired as rapidly as possible from the adjusting piece, the first round where ordered by the observer and the second round at a range 400 yards greater. When they have been brought to the vicinity of the target, the observer proceeds as follows:

(1) He notes the line established by the two ranging rounds and visualizes the gun-target line.

(2) He measures the deviation (in mils) between bursts, and converts this deviation to yards (fig. 32) by the method described in the example, paragraph 82c (1).

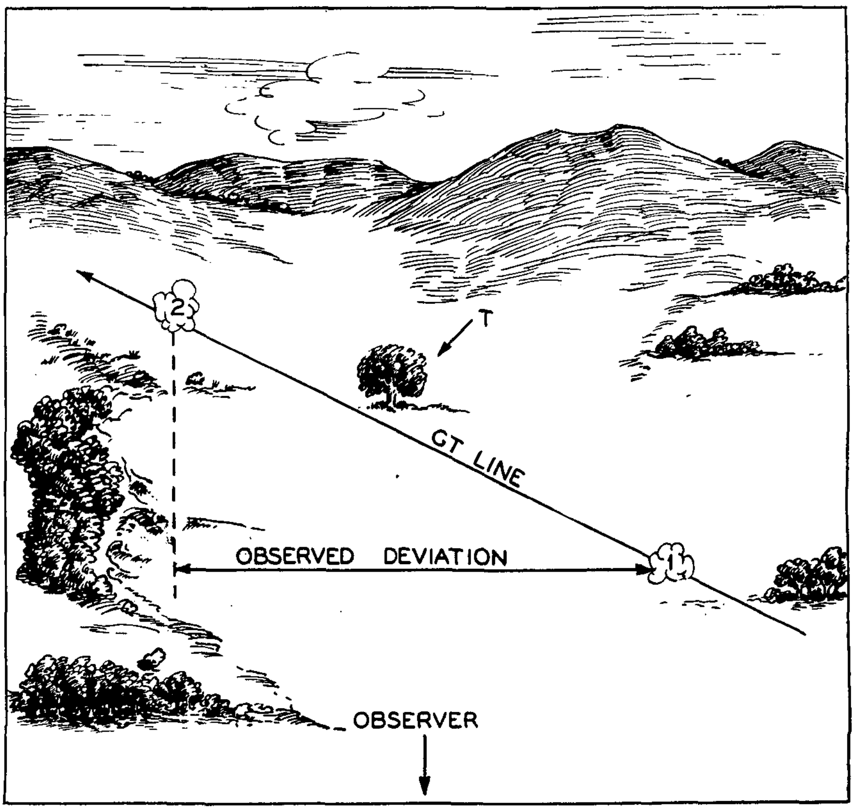


Figure 32. Observed deviation between ranging rounds.

(3) If the observed deviation between ranging rounds is 200 yards or less, range is the controlling element, and the observer uses *range-bracketing* procedure. If the observed deviation is greater than 200 yards, deflection is the controlling element, and the observer uses *deflection-bracketing* procedure.

b. When the observer desires ranging rounds fired, he includes in his initial fire message, FIRE RANGING ROUNDS. If these rounds are too far from the target to be of value to the observer, he gives appropriate corrections to move the bursts closer to the target and includes with his corrections, REPEAT RANGING ROUNDS. Corrections are based on the first round of the last two ranging rounds. If one or both of the rounds are lost, the observer may command LOST, REPEAT DEFLECTION, REPEAT RANGING ROUNDS, TIME FIRE, REPEAT RANGE, in order to obtain ranging rounds fired in the air.

c. If, in his initial fire message, the observer has included TIME FIRE (as the ammunition desired), and he also calls for ranging rounds, the ranging rounds are fired with time shell set to burst *on impact.* At the conclusion of firing ranging rounds, subsequent rounds in adjustment are fired with the appropriate site and fuze setting to give air bursts.

d. The observer should take full advantage of any sensings obtained from either or both of the ranging rounds.

101. DETERMINATION OF DEFLECTION FACTOR (S). a. If the observed deviation between ranging rounds is 200 yards or less, the distance is divided by 4 (since the rounds were fired 400 yards apart) and the quotient is used as S in yards.

b. If the observed deviation between ranging rounds is greater than 200 yards, the value of S corresponding to the observed deviation is as follows:

OBSERVED DEVIATION (yards)	S (yards)
225	68
250	80
275	95
300	113
325	139
350	181
375	269

It will be noted that for observed deviations exceeding 200 yards the value of S is no longer equal to approximately one-fourth the value of the observed deviation. Instead, the observer uses the following table of approximate values in order to obtain a usable S in deflection-bracketing.

FOR AN OBSERVED DEVIATION OF— (yards)	USE AN S OF— (yards)
250	80
300	100
350	200

For the larger values of the observed deviation, a precise determination of the value of S is not warranted, because dispersion and ground forms cause variations in its practical value throughout any given adjustment. However, the smaller the value of S, the more stable it appears on the ground and the more precisely it should be computed and applied.

c. The value of S in mils may be determined also:

(1) From the firing tables; (2) approximately, by computation, using the formula $S = \frac{1/10\ T}{R}$, if T is less than 600 mils. This value must be converted to S in yards.

d. In heavy artillery, or light and medium artillery when firing at long ranges or for destruction, the fire-direction center may make range changes by adding or dropping *forks* rather than making 100-yard changes. For simplicity, the observer continues to correct range in terms of hundreds of yards. The observer is notified when forks are used in order that he may determine new factors.

Example: An observer of a 155-mm howitzer battalion desires to destroy a small bridge within enemy lines. The mission requires a precision adjustment. From previous area fire missions in the vicinity of his new target, the observer has determined accurate factors to be used when range changes are made in *hundreds of yards.* However, he is notified by fire-direction center that range changes in his destruction mission will be made in *forks.* He orders ranging rounds fired in the vicinity of the bridge in order to determine the value of factors corresponding to a 1-fork change in range. These ranging rounds are fired *4 forks* apart in range. Throughout the mission, fire-direction center changes the range by 1 fork for each 100-yard change ordered by the observer.

e. Factors are corrected promptly if, during firing, they are observed to be considerably in error.

102. CORRECTIONS AND TERMS. The following are corrections and terms normally used by the observer:

a. FIRE MISSION—Warning order to alert the fire-direction center and to indicate that the message to follow is a request for fire.

b. LEFT (RIGHT) (so many yards)—To correct the deflection.

c. CLOSE (OPEN) SHEAF—To narrow (widen) the sheaf. An arbitrary change of 50 yards in width of sheaf is made by fire-direction center.

d. CONVERGED (so many-YARD) SHEAF—To obtain a converged sheaf (or a sheaf of any desired width).

e. CONVERGE ON NUMBER TWO (or other piece)—To obtain a sheaf converged on the desired piece.

f. UP (DOWN) (so many yards)—To correct for differences in altitude in the target area; to raise (lower) the height of burst in time area fire.

g. PLUS (MINUS) (so much) (in tenths of a second)—To increase (decrease) the time setting of time fuzes in a time registration.

h. ADD (DROP) (so many yards)—To increase (decrease) the range.

i. CLOSE—To indicate that the target is within 600 yards of friendly forward elements.

j. DEEP—To indicate that the target is more than 600 yards from friendly forward elements.

k. REPEAT DEFLECTION (RANGE)—To obtain fire at the same deflection (range) as the previous round or volley.

l. SALVO RIGHT (LEFT)—To obtain battery (platoon) salvos beginning with the right (left) piece.

m. FIRE FOR EFFECT—In area fire, to indicate that the adjustment is satisfactory and that the unit is to fire for effect. In precision fire, this term is not used as a command, but is used to refer to the rounds fired after the trial range has been determined.

n. SPECIAL CORRECTIONS—To indicate that a regular sheaf is desired; i.e., that individual corrections for lateral distribution and variations in range between pieces are necessary.

o. ERROR (followed by proper correction)—To change an erroneous correction to the proper correction.

p. LOST (followed by correction to obtain observation)—To indicate that the last round or volley was not observed.

q. SUSPEND FIRE—To interrupt firing for any reason prior to end of mission. It indicates that adjustment of fire will continue after a short delay.

r. MISSION ACCOMPLISHED—To cease firing on a target when mission is completed.

103. INITIAL FIRE MESSAGE. The initial fire message sent by the observer to the fire-direction center includes the following elements, in the sequence indicated:

Identification of the observer.

Warning order.

Location of target.

Nature of target.

Classification of fire.

Type of adjustment.

Type of ammunition.

Control.

a. Identification of the observer. The observer, when necessary, identifies himself, usually by use of a code word or words.

b. Warning order. The observer sends FIRE MISSION to alert the fire-direction center.

c. Location of target. The location of the target may be given in one of the following ways:

(1) By giving a shift in yards from a known point (fig. 33). The known point may be any point whose chart location is known to fire-direction center. The shift is given in the sequence: Known point, deflection, altitude, range; for example, FROM BASE POINT, LEFT 400, UP 30, ADD 600. The deflection and range corrections should be large enough to assure the bracketing of the target between the known point and the initial volley. If the altitude of the target is the same as the known point, that element is omitted. When firing time fire, the vertical control operator adds the desired height of burst to the observer's correction for altitude. If the deflection (range) is estimated to be the same as the known point, the observer sends REPEAT DEFLECTION (RANGE).

(2) By giving coordinates (grid, hectometric, or photo) referring to a map, photomap, or vertical or oblique photo.

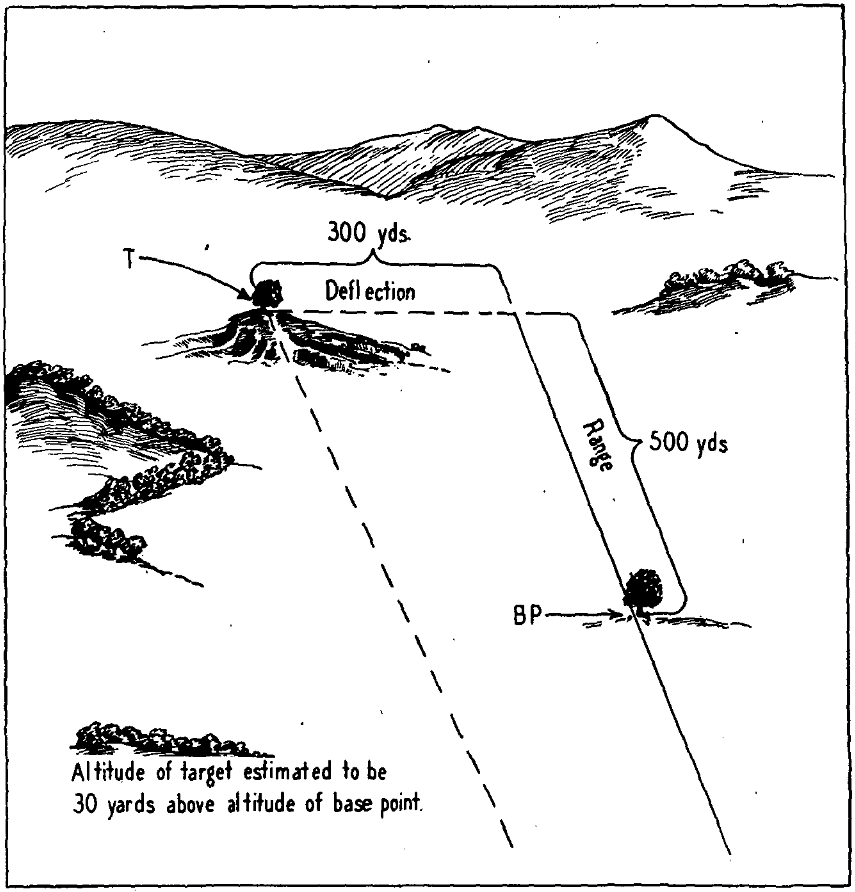


Figure 33. Designating the location of the target with respect to a known point. The observer sent to FDC:* FROM BASE POINT, LEFT 400, UP 30, ADD 600 *(to assure bracketing the target between the known point and the initial volley).

(3) By means of a geographic direction and distance from a known point, as FROM CR 224, NORTH 400, EAST 500, or FROM CR 932, NORTHEAST 600.

(4) By use of polar coordinates, as FROM RJ 615, AZIMUTH 3200, DISTANCE 900.

(5) By commanding a marking volley from which he can shift to his target. Examples:

MARK BASE POINT.

MARK CHECK POINT NO. 3.

MARK CODE COMPASS RIGHT 300, CODE RANGE ADD 1000 (prearranged code only). (See par. 86.)

d. Nature of target. The nature of the target consists of a description of the enemy installation, personnel, equipment, or activity which is observed. This description should be brief but should contain enough information to be a guide to the importance of the target, and to indicate the best manner of attack. Information of intelligence nature must be reported promptly but without delaying the fire mission.

e. Classification of fire. To indicate the relative proximity of the target to friendly troops the observer transmits CLOSE or DEEP. The use of this element is optional when adjusting ground artillery fire, but mandatory in the adjustment of naval gunfire.

f. Type of adjustment. The designation of type of adjustment may include: PRECISION REGISTRATION, DESTRUCTION, HIGH-ANGLE FIRE, also special sheaf or range spread desired, or any other special requirement. If salvo fire is desired, the observer sends SALVO RIGHT (LEFT). If no specific type of adjustment is designated, area fire methods (and platoon or battery volleys) will be used.

g. Type of ammunition. The observer designates the type of projectile and fuze desired. Choice of projectile and fuze depends upon effect sought (pars. 14 to 20, incl.). If no specific type of ammunition is designated, HE shell with quick fuze will be used.

h. Control. The observer's designation of control will consist of one of the following:

(1) WILL ADJUST. This indicates that the accuracy of the observer's location of the target is such that an adjustment is considered necessary and that the observer can adjust the fire. If observation is difficult or intermittent, the observer precedes WILL ADJUST by AT MY COMMAND. In this event, the observer transmits FIRE after receipt of *READY* from fire-direction center, and when he is in position to observe. This procedure remains in effect until a subsequent correction is followed by the command WHEN READY.

(2) FIRE FOR EFFECT. When transmitted as part of the initial fire message, this indicates that the observer considers his location of the target to be accurate, no adjustment necessary, and surprise fire desirable. He observes the initial fire for effect and, if necessary, sends appropriate corrections to increase the effect of subsequent fire on the target.

(3) CANNOT OBSERVE. This indicates that the observer will be unable to adjust the fire. Decision as to the advisability of firing the mission rests with the fire-direction center.

i. Examples of initial fire messages.

(1) FIRE MISSION
MARK BASE POINT
FIRE RANGING ROUNDS
PRECISION REGISTRATION
WILL ADJUST.

(2) FIRE MISSION
FROM BASE POINT
RIGHT 400
UP 40
ADD 600
THREE MACHINE GUNS
WILL ADJUST.

(3) FOX OBOE BAKER (Forward Observer, Battery B)
FIRE MISSION
JIG MIKE 9763
INFANTRY IN FOXHOLES
SALVO RIGHT
TIME FIRE
AT MY COMMAND
WILL ADJUST.

(4) FIRE MISSION
CONCENTRATION 32
INFANTRY IN OPEN
VT FUZE
FIRE FOR EFFECT.

(5) FIRE MISSION
(47.2-93.6)
INFANTRY ASSEMBLING
VT FUZE IN EFFECT
WILL ADJUST.

(6) Example of an illumination mission:
FIRE MISSION
FROM CHECK POINT 1
REPEAT DEFLECTION
DROP 400
TANK ASSEMBLY AREA (nature of target may be omitted for routine illumination)
ONE GUN (to indicate that one-gun illumination is desired)
ILLUMINATION
WILL ADJUST.

104. INFORMATION SENT TO OBSERVER. a. If a target is to be fired upon, fire-direction center furnishes the following information to the observer:

	Example
(1) Battery (batteries) to fire for effect.	(1) *BATTALION*
(2) Adjusting battery.	(2) *BAKER*
(3) Projectile and/or fuze.	(3) *TIME FIRE*
(4) Concentration number assigned.	(4) *CONCENTRATION NO. 30*
(5) Method of fire and range spread.	(5) *3 VOLLEYS, CENTER RANGE*
(6) Time of opening fire.	(6) *WHEN READY.*

b. If the mission cannot be fired, the observer is notified, *WILL NOT FIRE.*

c. The observer is informed *ON THE WAY* as each round or volley is fired during adjustment. As each unit starts fire for effect, the observer is informed; for example, *ABLE FIRING FOR EFFECT.* When firing medium and heavy artillery at long ranges and when firing high-angle fire with all calibers, the observer is sent the warning, *SPLASH,* five seconds prior to the end of time of flight of the round or volley. When the observer has sent AT MY COMMAND, fire-direction center transmits *READY* to indicate that pieces are ready to fire. Fire-direction center informs the observer when fire for effect has been completed; for example, *ROUNDS COMPLETE, ABLE, BAKER, CHARLIE,* or *ROUNDS COMPLETE, ALL BATTALIONS.*

105. SUBSEQUENT CORRECTIONS. a. Any element of subsequent corrections, other than the correction for deflection and range, may be omitted if no change in that element is desired. *A correction for deflection and range always must be given.* If it is desired to fire the same deflection (range) as the last rounds, the observer sends REPEAT DEFLECTION (RANGE).

b. When the initial round or volley shows that either range or deflection is greatly in error, a bold change of the element in error is made, even though procedure calls for rounds to be brought to the line by correction of the other element.

c. Subsequent corrections are given in the following sequence:

(1) Deflection correction.

(2) Distribution correction.

(3) Height of burst correction.

(4) Time correction (in time registration).

(5) Change in any special requirements (for example, to change from volley to salvo fire during area adjustment).

(6) Change in number of rounds to be fired (in precision fire).

(7) Change in ammunition (for example, to change from fuze delay to time fire).

(8) Range correction.

106. CORRECTION OF ERRORS. When an observer sends an erroneous correction, he corrects it by sending the *proper* correction, preceded by ERROR. For example, the observer has given LEFT 200, ADD 400. He desires to change the deflection correction to RIGHT 200. To correct his error, the observer sends ERROR, RIGHT 200, ADD 400. If the observer has transmitted his initial fire message and finds that he has made an error in one of the elements listed in paragraph 103, he sends ERROR, followed *only* by the information pertaining to the element in error. The remaining elements of the initial fire message need not be retransmitted. If any element of the message has been omitted erroneously, the observer sends that element to fire-direction center as a separate transmission without repeating the entire initial fire message.

CHAPTER 3
CONDUCT OF FIRE BY RANGE-BRACKETING PROCEDURE

Section I. GENERAL

107. EMPLOYMENT. Range-bracketing procedure is employed when the observed deviation between ranging rounds is *200 yards or less* (pars. 100 and 101). The observer is then on or near the *GT* line, and he can determine deflection errors more accurately than range errors. Range, therefore, is the controlling element.

108. RANGE BOUNDS. a. First bounds. After a round or volley has been sensed positively, the first range bound is made large enough to bracket the target. A range bound of less than the bracket sought is not made until that bracket has been obtained. Initial range changes are made in hundreds of yards. When the approximate amount of range error cannot be estimated, the following may be used as a guide in determining the amount of the initial range bound.

(1) 100 yards (or 1 fork), for map data corrected.

(2) 200 yards (or 2 forks), when using map data or when making a small shift from a previous target.

(3) 400 yards (or 4 forks), when using data obtained by approximate methods.

b. Bounds close to friendly troops. Fire close to friendly troops is opened with a range which is surely safe. Range is then changed by bounds which are safe, until a bracket or a correct range is obtained.

Section II. PROCEDURE

109. ADJUSTMENT, PRECISION FIRE. a. General. Adjustment is by single piece. Each round is sensed for range. The object of adjustment is to obtain a *trial range.* The trial range is the range for the center of a 100-yard (or 1 fork) range bracket, or a range giving a target

hit. In order to obtain a trial range, an initial range bracket is sought; thereafter, the bracket is successively split until the trial range is determined.

b. Ranging rounds. Unless the observer has previously determined the gun-target line and the value of *S* in the vicinity of his target, he orders ranging rounds fired, and computes *S* (pars. 100 and 101). *S* is corrected promptly if determined by firing to be considerably in error.

c. To get on the line. When a burst cannot be sensed positively for range because of its deviation from the *OT* line, the amount of the deviation is determined, in yards, and a deflection correction equal to that amount is made to place the next burst on the *OT* line.

d. To stay on the line. When a line shot is obtained, a shift of one *S* is made for each 100-yard range change in order to keep the burst on the *OT* line. When a burst off the *OT* line is sensed positively for range, the observer's deflection correction combines: (1) the shift to bring the off-line burst to the line and, (2) the shift to stay on the line when the range is changed. For example: the observer senses a burst *short* (50 yards right of the *OT* line); he decides to increase the range 400 yards; the *S* is 30; the piece is on the right. A correction of LEFT 50 would place the off-line burst on the line, and a shift of RIGHT 120 (four *S's*) accompanies the range change of ADD 400 yards; the net correction is RIGHT 70 (LEFT 50 to get on, RIGHT 120 to stay on). The observer sends: RIGHT 70, ADD 400.

110. FIRE FOR EFFECT, PRECISION FIRE. a. Starting fire for effect. Fire for effect is started when the trial range is determined. Each round is sensed for range and deflection; for example, *short, deflection short; over, deflection doubtful.*

b. Sensing by rule. When deflection is correct to within 40 yards or ½ *S,* whichever is smaller, rounds bursting on the side of the *OT* line away from the guns are sensed *over* for range; those bursting on the side of the *OT* line toward the guns are sensed *short* for range. In range-bracketing procedure, caution must be exercised when sensing by rule, because in this procedure deflection is not sensed during adjustment, and may be abnormally in error unless bursts have been brought very close to the *OT* line. Range should be sensed by rule only when bursts cannot be sensed positively on the *OT* line or on terrain. Deflection can never be sensed by rule.

c. Direction. On entering fire for effect, a deflection shift is made which will place the burst on the *OT* line. Based upon positive sens-

ings, the deflection is changed $\frac{1}{2}$ *S* or 10 yards (whichever is greater) until a deflection bracket is obtained. Thereafter it is split successively until the deflection is correct. Deflection is correct when a target hit is obtained, when a 10-yard deflection bracket (20-yard, for *GT* ranges greater than 10,000 yards) is split, or when a *deflection over* and a *deflection short* are obtained with the same deflection setting.

d. Range. A group of six range sensings is required. If the trial range is obtained by a target hit, five additional rounds are fired at that range. A positive sensing obtained during adjustment at a range used in fire for effect is counted as a round of fire for effect. When the trial range is the center of a 100-yard (or 1-fork) bracket, groups of six rounds are fired in half-groups of three until deflection is correct, or if time permits rounds should be fired singly in order to facilitate deflection adjustment. The observer specifies the number of rounds to be fired in each case. After the first three rounds, the observer sends REPEAT RANGE if both *overs* and *shorts* are obtained. If all rounds are *short* (*over*) the observer sends ADD (DROP) 50 and fires enough rounds to complete the group of six. If any rounds are *doubtful* for range the observer sends REPEAT DEFLECTION, ONE (TWO) (FOUR) ROUNDS, REPEAT RANGE. This command for number of rounds remains in effect until changed by the observer.

e. Report of sensings. After six usable rounds have been obtained, the observer reports the range sensings for all six rounds. The fire-direction center then computes the adjusted elevation. If the mission is destruction, the observer continues fire for effect until the target is destroyed; for example, 4 OVERS, 2 SHORTS, REPEAT DEFLECTION, ADJUSTED RANGE. If the mission is registration, the observer indicates when it is completed by reporting REGISTRATION COMPLETE. For example: 4 OVERS, 2 SHORTS, LEFT 5, REGISTRATION COMPLETE.

f. Types of registration. (1) SIX-ROUND REGISTRATION. This is the type normally used. The adjusted elevation is computed by fire-direction center as follows:

(*a*) If the first three rounds fired for effect are all in the same sense and the observer has made the appropriate range change and has fired three more rounds, all six rounds are considered to have been fired at the mean of the two elevations used.

(*b*) With an equal number of *overs* and *shorts*, the adjusted elevation is the elevation at which the group was fired.

(*c*) With unequal numbers of *overs* and *shorts,* the difference between the number of *overs* and *shorts* (neglecting target hits) is determined. Apply the formula:

$$\left(\frac{\text{Difference in number of overs and shorts}}{2 \times \text{number of rounds fired}}\right) \times F,$$

and add (subtract) the result to (from) the elevation used (or mean elevation). NOTE: If there were more *overs* than *shorts,* subtract; if there were more *shorts* than *overs,* add. In high-angle fire, the correction is applied in the opposite direction (ch. 6, sec. III).

(*d*) Adjusted elevation is taken to the nearest mil. The fork used for the computation corresponds to the elevation at which the group was fired.

(2) TWELVE-ROUND REGISTRATION. Normally, the six-round registration is sufficiently accurate for the determination of corrections. However, when a large quantity of ammunition is to be expended on unobserved fires, or when surprise fire must be placed close to supported troops, a more accurate registration is indicated. Additional accuracy (and verification) is obtained by firing an additional group of six rounds at the adjusted elevation, and making one-half the correction computed as in f (1) above.

(3) SPECIAL REGISTRATION. A six-round registration normally should be used to insure accuracy and verification of sensings. A six-round registration has a much higher validity than a four-round registration. However, a six-round registration may be precluded by special conditions, such as a target obscured by smoke prior to completion of mission, ammunition shortage, or the necessity of shortening the mission in adjustment by high-performance aircraft. Four rounds are the minimum that should be used. Computations are made as in f (1) above, and are based on the number of rounds as follows:

(*a*) With an equal number of *overs* and *shorts,* the adjusted elevation is the elevation (or mean elevation) at which the group was fired.

(*b*) With unequal numbers of *overs* and *shorts,* first determine the difference between the number of *overs* and *shorts* (neglecting target hits). Apply the formula given in f (1) above and add (subtract)) the result to (from) the elevation used (or mean elevation).

g. Destruction. When the mission is destruction, the procedure is initially the same as in f (1) above. Range changes are made in forks instead of hundreds of yards. Fire is continued until destruction is complete. Elevation is adjusted after each group of six sensings; the change is one-half the computed amount after the second group, one-

third after the third, and one-fourth thereafter. Quadrant elevation should be taken to the nearest tenth of a mil after the adjusted elevation for the second group is computed. Generally, quick fuze is used during adjustment and in the first group of six rounds in fire for effect, in order to avoid sensing on ricochet bursts; delay fuze is used in subsequent fire for effect.

h. Time registration. (1) Following an impact registration with time shell, the observer begins the time registration by commanding REPEAT DEFLECTION, ONE ROUND, TIME FIRE, ADJUSTED RANGE. Since the observer does not know the time setting, he changes the time setting by sending PLUS (MINUS) (so much) (in tenths of a second, usually in multiples of 0.4 second). If the initial round is a graze burst, the usual change is MINUS 8, until an air burst is obtained. When an air burst is obtained on the initial round, the multiple of 0.4 to change is indicated by the height of burst. After a bracket of 0.4 second has been obtained, two rounds are fired at the center of the bracket; for example, the observer commands REPEAT DEFLECTION, PLUS (MINUS) 2, 2 ROUNDS, REPEAT RANGE. A group of four time sensings is required; rounds are fired in half-groups of two.

(2) If the first half-group results in one *air* and one *graze,* the observer sends REPEAT DEFLECTION, REPEAT RANGE, in order to obtain two more rounds at the same time setting. If both of the rounds in the first half-group are *air* (*graze*), one more round is fired at the *graze* (*air*) limit of the bracket. After four usable rounds have been obtained, the observer reports the time sensings for all four rounds; for example, 3 AIRS, 1 GRAZE, TIME REGISTRATION COMPLETE. The fire-direction center then computes the adjusted time as follows:

(*a*) With an equal number of *airs* and *grazes,* the adjusted time is the time (or mean time) at which the group was fired.

(*b*) With a preponderance of *airs* (*grazes*), the adjusted time is 0.1 second more (less) than the time (or mean time) at which the group was fired.

(3) Time registration, as outlined above, is not always sufficiently accurate for surprise fires delivered close to supported troops. Inaccuracy is due to the limited number of rounds employed to determine the time correction. When surprise fires are to be delivered, the time correction should be verified by adjusting on an auxiliary target. If this is impracticable, the time registration should be repeated firing two groups of four rounds in effect, applying to the correction of the first group one-half the correction indicated by the second group.

i. Verification. No registration should be accepted as correct if fire for effect contains only a single round in one sense, unless there is evidence that the single sensing is not erratic. For example, in a precision registration, if fire for effect gives five *overs* and one *short*. unless it has been observed that the *overs* are so close as to rule out the possibility that the *short* is an erratic round, fire for effect should be repeated in half-groups of three, starting at the adjusted elevation. If the first half-group of three rounds results in both *overs* and *shorts,* or all *shorts,* a second series is fired to complete the group of six rounds, and the adjusted elevation is computed as for a twelve-round registration. If the first half-group results in three rounds in the same sense as the five *overs* (above), the previous adjusted elevation is disregarded. The range is changed 50 yards (or one-half fork) in the appropriate direction, three more rounds are fired, and the adjusted elevation is computed based upon the mean range at which the group was fired. Similarly, in a time registration containing only a single *graze,* if the air bursts are close to the ground they may be assumed to verify the correctness of the graze. If the registration contains only a single *air,* there can be no certainty of its correctness and registration must be verified. This is accomplished by repeating fire for effect in half-groups of two rounds, beginning at the previous adjusted time. If the first half-group results in one or two air bursts, the last four sensings obtained are used to compute a new adjusted time. If the first half-group results in two graze bursts, time is decreased 0.2 second and a second half-group is fired. If the second half-group results in one or two air bursts, a new adjusted time is computed using the last four sensings obtained. If the second half-group results in two graze bursts, the adjustment is begun anew.

111. ADJUSTMENT, AREA FIRE. a. General. Normally, fire is opened with platoon volleys. A parallel sheaf is used during adjustment unless the observer designates otherwise. The object of adjustment is to enclose the target within a range bracket of suitable depth, with deflection correct, or to obtain target hits. This is accomplished by seeking an initial range bracket, and thereafter by successively splitting the bracket. Ranging rounds may be ordered if desired; they are fired by an interior piece. When ammunition must be conserved, the adjustment may be started with one piece, preferably an interior one; the battery is brought in as desired. Quick, delay, time, or VT fuze may be used, depending upon the effect sought. The height of burst (in time fire) and range of the volley as a whole are sensed; for example, *mixed, short; graze, over.*

b. Direction and distribution. The deviation of the burst center with respect to the *OT* line is determined. The burst center is then brought to and kept on the *OT* line by the same procedure as for a single burst in precision fire (pars. 109c and d). At any time after the initial volley, the observer may widen, narrow, or converge the sheaf as desired.

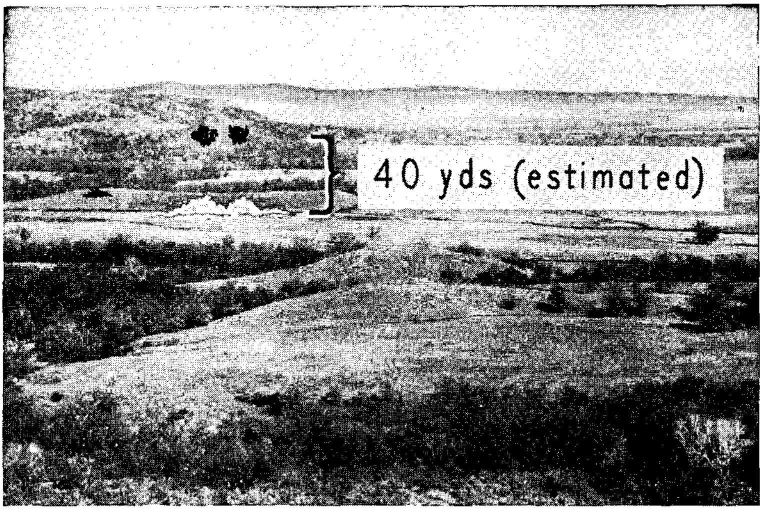


Figure 34. Sensing height of burst prior to starting fire for effect. In the example above, the observer's correction for height of burst is DOWN 20.

c. Height of burst. In time fire, height of burst is adjusted by changing site (fig. 34). Range adjustment preferably is made with air bursts. A good height of burst during adjustment is one which gives range sensings. When the initial volley results in all *grazes,* a correction of UP 40 is given. When the volley results in *mixed* or *mixed graze,* a correction of UP 20 is given. If a volley results in *mixed air,* no change is made in height of burst. When a volley results in *airs,* site can be changed to give the desired height of burst. When firing against targets located on steep slopes or on extremely irregular ground, the observer must exercise caution in adjusting the height of burst; an air burst below the level of the target should be treated as a *graze;* a graze burst above the level of the target should be treated as doubtful for height of burst.

d. Range. Range changes are made in hundreds of yards until a range change of less than 100 yards is indicated. Normally, a range

change of less than 50 yards is not made. The bracket sought in adjustment depends upon the nature of the target and on knowledge of its location. (Once fire for effect is started, ineffective ranges of the bracket are eliminated.) A bracket of 200 yards is appropriate for a target whose location is known only approximately, such as a target in the vicinity of a terrain feature. A smaller bracket or an effective single range may be sought for a visible target. When fire of additional units is to be brought in following adjustment of a battery, or where fire is close to supported troops, a 100-yard bracket is sought in adjustment, and fire for effect is started at its center. When indirect laying is used against a rapidly moving target, fire is placed in the path of the target so as to meet it. A deep bracket, quickly obtained, may indicate a range to be used for effect. Under certain circumstances it may be possible to split the bracket proportionately; for example, having made a 600-yard range change, ADD 600, the observer notes that the target is about one-third of the way between the resulting volley and the previous volley. His next correction for range should be DROP 200. If during adjustment a *bracketing* volley (salvo) or a target hit is obtained, fire for effect is started immediately.

112. FIRE FOR EFFECT, AREA FIRE. a. Starting fire for effect. Fire for effect is started when a suitable adjustment has been obtained; that is, when deflection and range are correct, or when effective fire will result with the next split in bracket. In time fire, fire for effect is not started until the height of burst is correct (fig. 35), unless the observer is certain that his next correction for site will result in the correct height of burst. Height of burst (in time fire), range, and deflection of each volley as a whole are sensed; for example, *mixed air, over, deflection over.* When a correct deflection is established, deflection sensings may thereafter be omitted.

b. Fuze. If ricochet action was sought in adjustment, the use of delay fuze is continued in fire for effect when at least 50 percent of the bursts which established the bracket for fire for effect were ricochets. If fewer than 50 percent of these bursts were ricochets, VT or quick fuze is used in fire for effect. If during fire for effect fewer than 50 percent of the bursts are ricochets, fuze is changed for subsequent fire for effect. When VT fuze is used, the fire-direction center makes the appropriate change in site. On wet terrain or in heavy foliage when the effect of VT fuze cannot be observed, the observer should adjust with quick fuze and order VT fuze when going into fire for effect.

Figure 35. Height of burst correct (approximately 20 yards).

c. Direction. On entering fire for effect, a deflection shift is made which will place the burst center on the *OT* line. Based upon positive deflection sensings, the deflection is changed by an amount equal to the deviation of the burst center from the *OT* line. Deflection is correct when rounds from the center pieces bracket the center of the target for deflection.

d. Distribution. Normally, in fire for effect a parallel sheaf is used when firing light and medium artillery. An open sheaf is used when special corrections are applied or when firing heavy artillery. However, the observer may narrow, widen, or converge the sheaf to fit a particular target. When the target is too wide to be covered effectively by an open sheaf and additional batteries are not available, the target is attacked by successive shifts.

e. Height of burst. In time fire, the site change upon entry into fire for effect should result in a height of burst of 20 yards at the center of the target. Fire for effect should not be started if the last volley consisted entirely of graze bursts. The height of burst above the target may be estimated by comparison with known dimensions of objects at the same distance from the observer. The smoke of 105-mm

and 155-mm HE shell bursts is about 10 yards in diameter at the instant of bursting.

f. Range. Fire for effect is started at the center range of the bracket selected. The initial range bracket for fire for effect may be the one obtained from adjustment or one that is slightly removed, as in cases of adjustment on an auxiliary target, a hillcrest, the near edge of a wood, or an adjusting point off the center of the target; for example, a bracket may be obtained on the near edge of a wood, and fire for effect delivered within the wood. Unless the observer otherwise designated in his initial fire message, or directs otherwise upon entering fire for effect, a single battery will fire through a 200-yard zone; the battalion normally will fire at center range unless coverage of a larger area is desired. Other than a 200-yard zone (for a single battery) may be obtained by commanding 100-YARD ZONE, or SINGLE RANGE. When a single range is used, the battery fires several volleys initially; if a preponderance of *overs* or *shorts* results, the observer corrects the range to center the fire on the target. During fire for effect, ineffective ranges are discarded, additional ranges may be added to include the target, and direction and range may be changed to conform with movement of the target or with additional information on its location. If fire for effect was accurate but insufficient, the observer may command REPEAT FIRE FOR EFFECT. If a single battery has fired through a zone, and further fire is desired, the observer may select the best single range and command further fire for effect; for example, REPEAT DEFLECTION, SINGLE RANGE, ADD 50, REPEAT FIRE FOR EFFECT.

g. Report of observer. Upon completion of fire for effect the observer sends MISSION ACCOMPLISHED (if fire has been effective and sufficient), and reports the effect which he has observed; for example, MISSION ACCOMPLISHED, FIRE EFFECTIVE, INFANTRY DISPERSED.

113. OBSERVER ON OR VERY NEAR GT LINE (Axial observation).

a. When the observer is on or very close to the *GT* line (with an *S* of less than 10) his problem is considerably simplified. During adjustment, particularly when a large range change is made, the *S* should be employed in order to keep bursts on the *OT* line and to facilitate sensing. However, during fire for effect it is not necessary to bracket the deflection since the deflection error can be measured precisely and correct deflection should be obtained by making a single shift.

b. When the *S* is less than 10 yards, range cannot be sensed by rule, since deflection dispersion may lead to erroneous range sensings.

Section III. SUMMARY OF PRINCIPLES AND EXAMPLES, RANGE-BRACKETING

114. GENERAL. a. Employ range-bracketing procedure when the observed deviation between ranging rounds is *200 yards or less.*

b. Bring bursts to the *OT* line by making appropriate *deflection* corrections.

c. Keep bursts on the *OT* line by shifting deflection one *S* for each 100-yard range change.

115. PRECISION FIRE. a. Adjustment. The object of adjustment is to determine the *trial range.* The trial range is the range for the center of a 100-yard (or 1-fork) range bracket, or a range giving a target hit.

b. Fire for effect. (1) Start fire for effect at the trial range, and with a deflection correction which will place the burst on the *OT* line. The rounds are fired singly or in half-groups of three.

(2) Based on positive deflection sensings, the deflection is moved ½ *S* or 10 yards, whichever is greater, until a deflection bracket is obtained. Thereafter, the bracket is split until the deflection is correct. Deflection is correct when a target hit is obtained, when a 10-yard deflection bracket (20-yard for *GT* ranges greater than 10,000 yards) is split, or when *deflection over* and *deflection short* are obtained with the same deflection setting.

(3) Obtain and report to the fire-direction center a group of six usable range sensings.

c. Time registration. (1) Following an impact registration with time-fuzed shell, begin the time registration at the *adjusted range* obtained from the impact registration.

(2) Change the time setting in multiples of 0.4 second until a bracket of 0.4 second is established.

(3) Split the 0.4-second bracket, obtain four time sensings, and report them to fire-direction center.

116. AREA FIRE. a. Adjustment. (1) The object of adjustment is to enclose the target within a range bracket of suitable depth, with deflection correct, or to obtain target hits. A bracket of 200 yards is appropriate for a target whose location is known only approximately; a smaller bracket or an effective single range may be sought for a visible target. A 100-yard bracket should be obtained when additional batteries or battalions are to fire for effect.

(2) Select the type of ammunition which will be most effective against the target.

(3) Bring the burst center to the *OT* line by appropriate deflection corrections.

(4) In time fire, adjust the height of burst to 20 yards above the center of the target by correcting site. Fire for effect is not started until the height of burst is correct, unless the observer is certain that his next correction will result in the correct height of burst.

(5) If a bracketing volley or a target hit is obtained, start fire for effect immediately.

b. Fire for effect. (1) Start fire for effect when deflection and range (and height of burst in time fire) are correct, or when effective fire will result from the next split in bracket.

(2) Start fire for effect at the center range of the bracket selected.

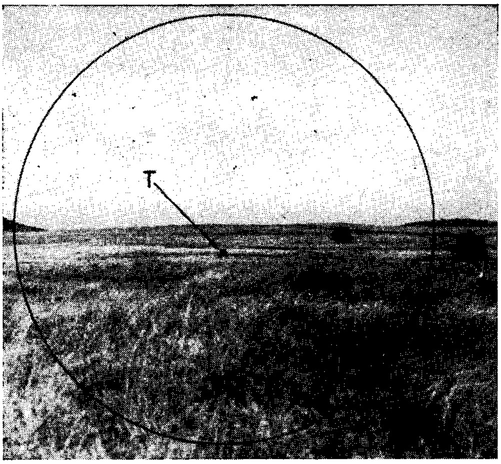
(3) Upon entering fire for effect, center the fire on the target or area to be covered by making an appropriate deflection change.

(4) Improve the range if the preponderance of the fire for effect is over or short. Improve the deflection when positive deflection sensings are obtained. Deflection is correct when rounds from the center pieces bracket the center of the target for deflection.

(5) If fire for effect is ineffective or insufficient, make necessary corrections and command additional fire for effect.

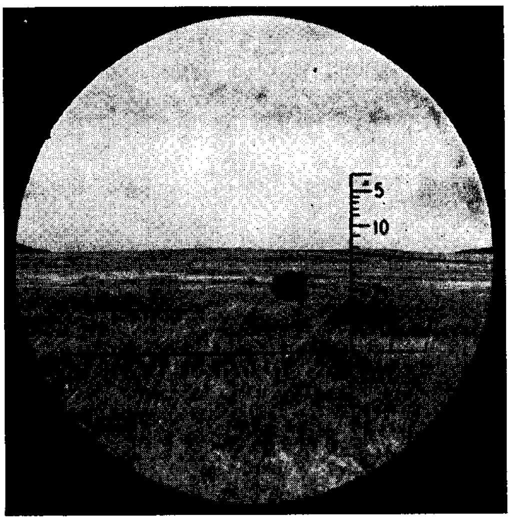
(6) Upon completion of fire for effect, send MISSION ACCOMPLISHED and report the effect observed.

117. ILLUSTRATIVE EXAMPLES. a. Range-bracketing precision. Target, base point; mission, registration; materiel, 105-mm howitzer; ammunition, HE shell, quick fuze.

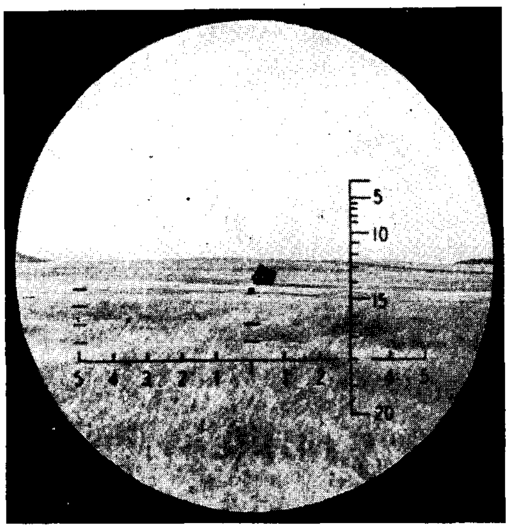
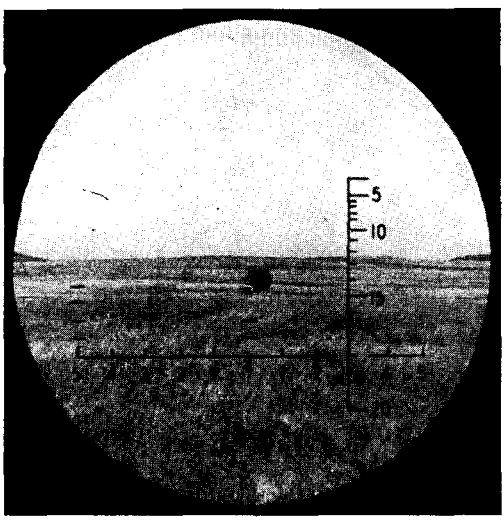
Messages, corrections, and commands	Results	Snsiegn RN	Snsiegn DF
Observer to FDC (initial fire message): FIRE MISSION, MARK BASE POINT, FIRE RANGING ROUNDS, PRECISION REGISTRATION, WILL ADJUST. FDC to Observer: *BAKER,* *RANGING ROUNDS,* *FUZE QUICK,* *BASE POINT,* *WHEN READY....* *ON THE WAY.*		?	

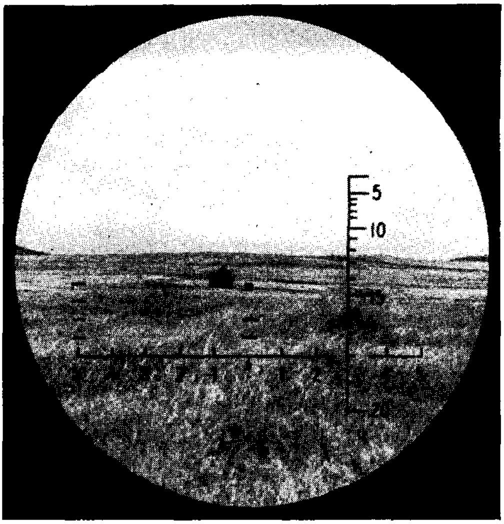
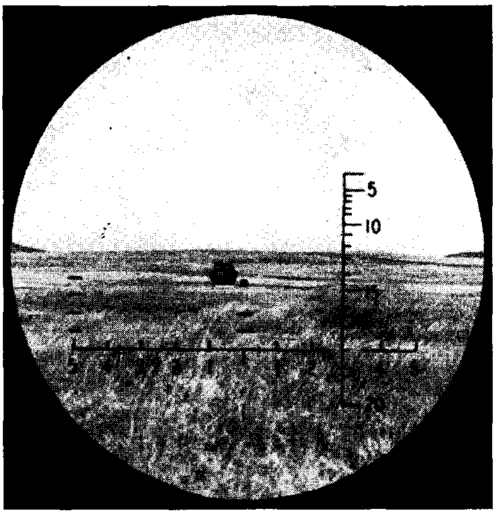
Remarks: *OT* distance from map = 2000 yards. With field glasses, observer measures 40 mils between ranging rounds. Observed deviation = 80 yards (40 × 2). *S* = 20 yards (80/4). Guns to right rear. Range-bracketing to be used. No range sensing obtained.

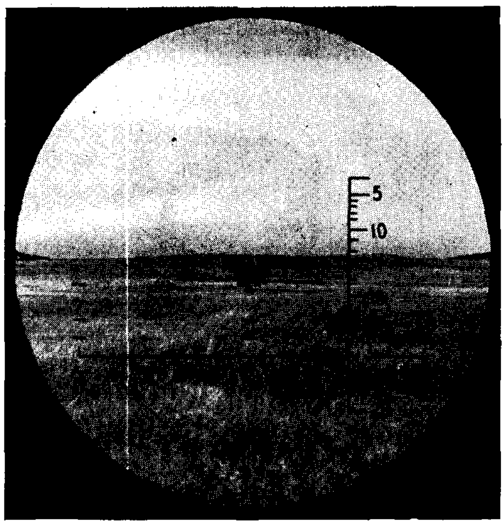
First ranging round is 80 mils right of *OT* line. Observer determines shift of 160 yards (80 × 2) necessary to bring burst to *OT* line.

Observer to FDC: LEFT 160, REPEAT RANGE. FDC to Observer: *ON THE WAY.*		—	

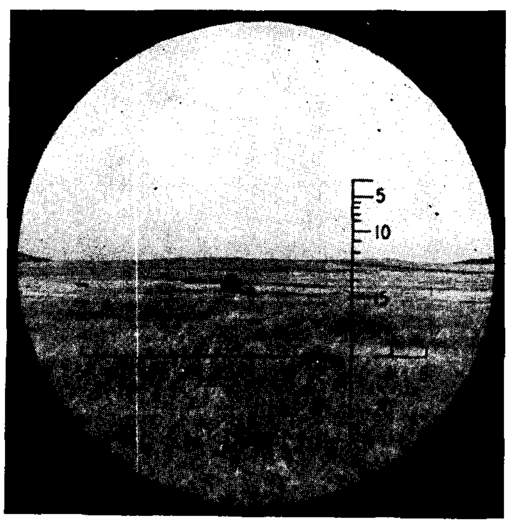
Remarks: Small deviation is ignored. Observer decides that 200-yard range change should give a range bracket.

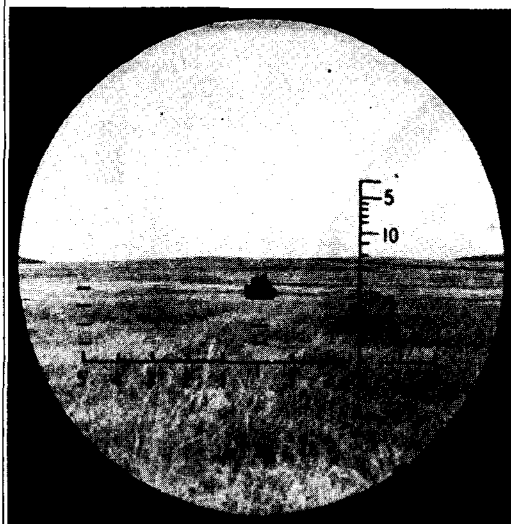
Messages, corrections, and commands	Results	Sensing	
		RN	DF
Observer to FDC: RIGHT 40, ADD 200. FDC to Observer: *ON THE WAY.*		+	
Observer to FDC: LEFT 20, DROP 100. FDC to Observer: *ON THE WAY.*		+	

Messages, corrections, and commands	Results	Sensing	
		RN	DF
Observer to FDC: LEFT 10, 3 ROUNDS, DROP 50. FDC to Observer: *ON THE WAY*.		+	?
		+	?

Messages, corrections, and commands	Results	Sensing RN	Sensing DF
		+	+

Remarks: Because deflection is *over*, deflection is changed 10 yards in the proper direction. Since all rounds are *over* for range, range must be decreased 50 yards. (First two rounds in fire for effect were sensed on rule.)

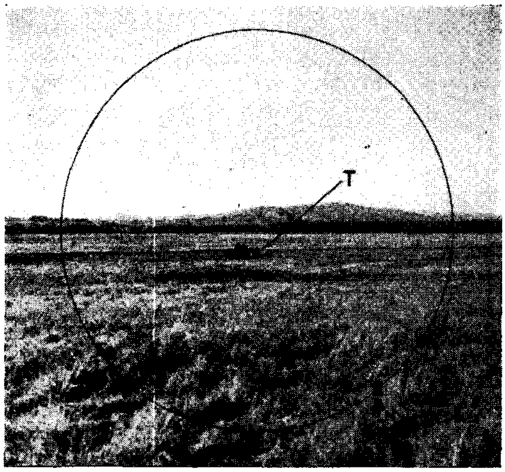
Observer to FDC: LEFT 10, 2 ROUNDS, DROP 50. FDC to Observer: *ON THE WAY.*		+	?

Messages, corrections, and commands	Results	Sensing	
		RN	DF
		—	—

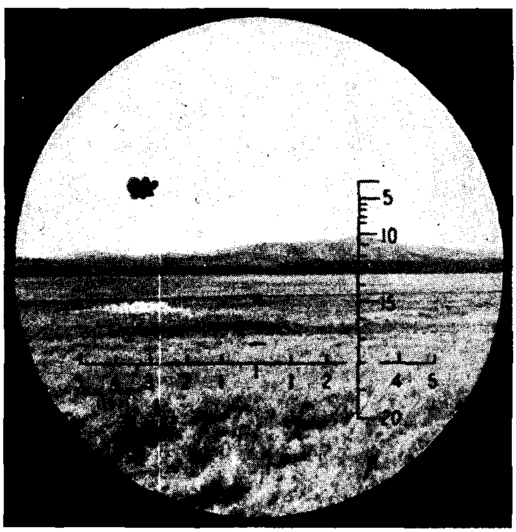
Remarks: Deflection will be correct when 10-yard deflection bracket is split. Round previously fired at this limit of bracket (first round following ranging rounds) resulted in range *short*. It is used as one round in effect.

Observer to FDC: 4 OVERS, 2 SHORTS, RIGHT 5, REGISTRATION COMPLETE.			

b. Range-bracketing time registration. Target, check point; mission, time registration (it is assumed that the observer had just completed a precision registration on the check point using time-fuzed shell on impact); materiel, 105-mm howitzer; ammunition, HE shell, fuze M54; guns to left rear.

Messages, corrections, and commands	Results	Sensing
Observer to FDC: REPEAT DEFLECTION, ONE ROUND, TIME FIRE, ADJUSTED RANGE. FDC to Observer: *ONE ROUND,* *TIME FIRE,* *ON THE WAY.*		G

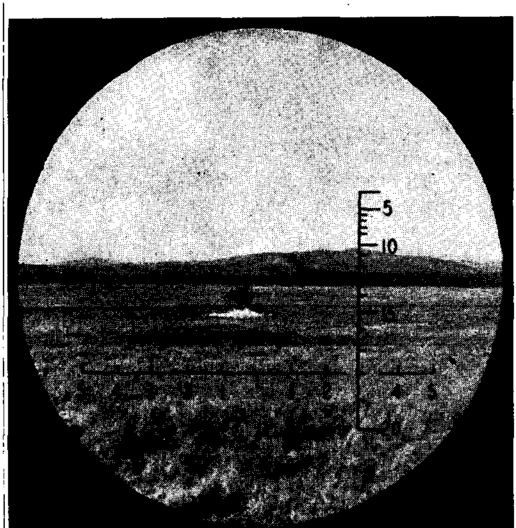
Remarks: Observer decides to change time setting 0.8 second.

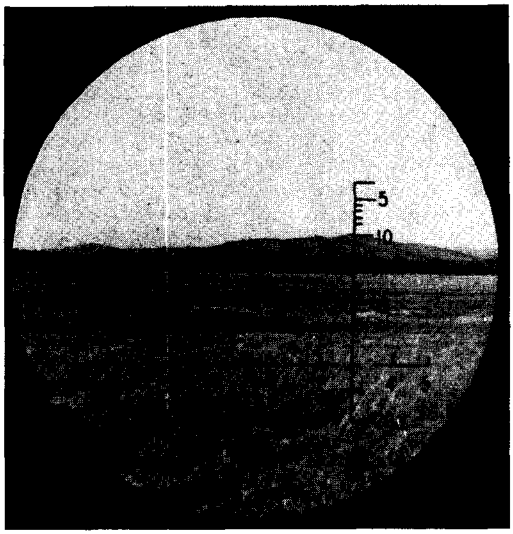
Messages, corrections, and commands	Results	Sensing
Observer to FDC: REPEAT DEFLECTION, MINUS 8, REPEAT RANGE. FDC to Observer: *ON THE WAY.*		A

Remarks: Bracket of 0.8 second has been obtained.

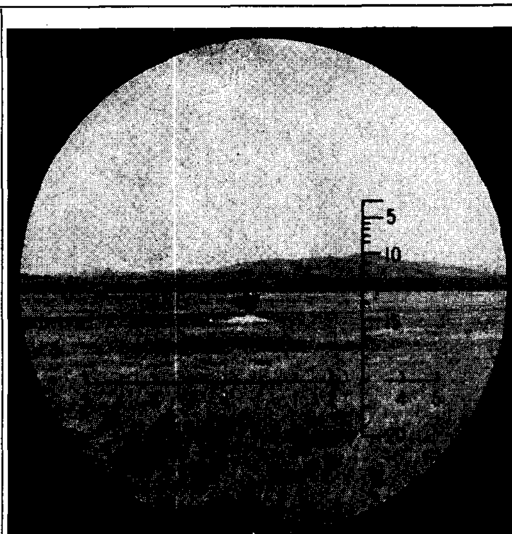
Messages, corrections, and commands	Results	Sensing
Observer to FDC: REPEAT DEFLECTION, PLUS 4, REPEAT RANGE. FDC to Observer: *ON THE WAY.*		A

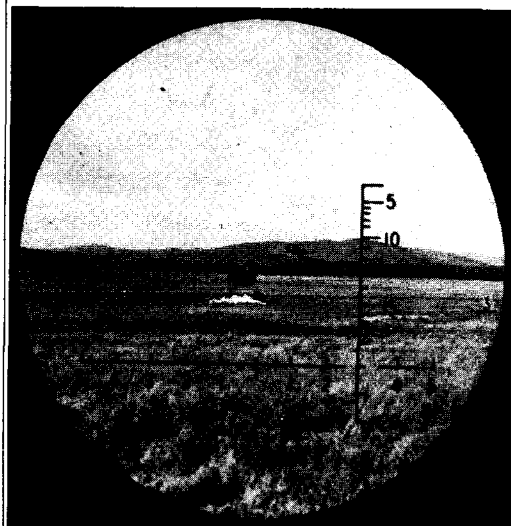
Remarks: Observer has obtained 0.4-second bracket. Next, this is split and two rounds fired at center.

Observer to FDC: REPEAT DEFLECTION, PLUS 2, 2 ROUNDS, REPEAT RANGE. FDC to Observer: *ON THE WAY.*		A

Messages, corrections, and commands	Results	Sensing
		G

Remarks: Two more rounds must be fired at the same time setting to obtain four time sensings.

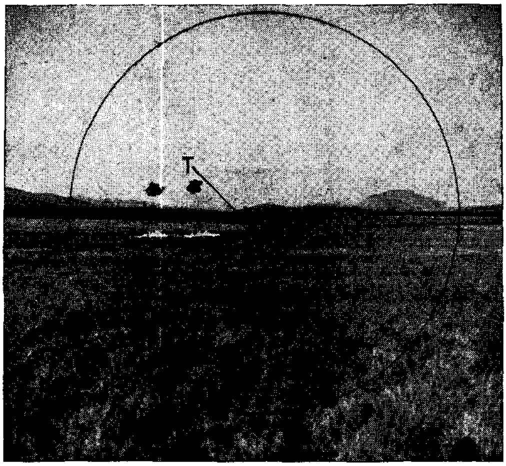
Observer to FDC: REPEAT DEFLECTION, REPEAT RANGE. FDC to Observer: *ON THE WAY.*		A

Messages, corrections, and commands	Results	Sensing
		A

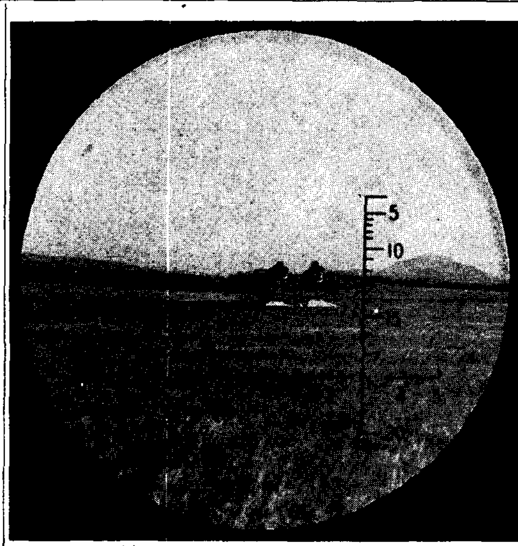
Remarks: Four time sensings have been obtained. These are reported to the fire-direction center. Registration is now complete.

Observer to FDC: 3 AIRS, 1 GRAZE, TIME REGISTRATION COMPLETE.		

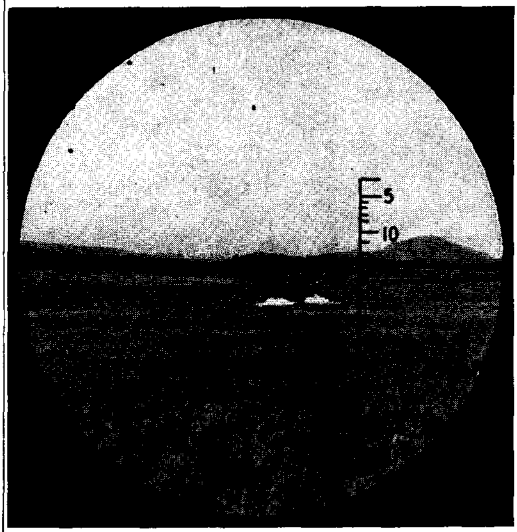
c. Range-bracketing area fire. Target, enemy mortars in vicinity of an adjusting point; mission, neutralization; materiel, 105-mm howitzer; ammunition, HE shell (both M48 and M54 fuzes in battery).

Messages, corrections, and commands	Results	Sensings	
		HB	RN
Observer to FDC (initial fire message): FIRE MISSION, FROM BASE POINT, RIGHT 400, DOWN 20, ADD 600, ENEMY MORTARS, TIME FIRE, WILL ADJUST. FDC to Observer: *BATTALION,* *BAKER,* *TIME FIRE,* *CONCENTRATION 7,* *2 VOLLEYS,* *CENTER RANGE,* *WHEN READY....* *ON THE WAY.*		A	?

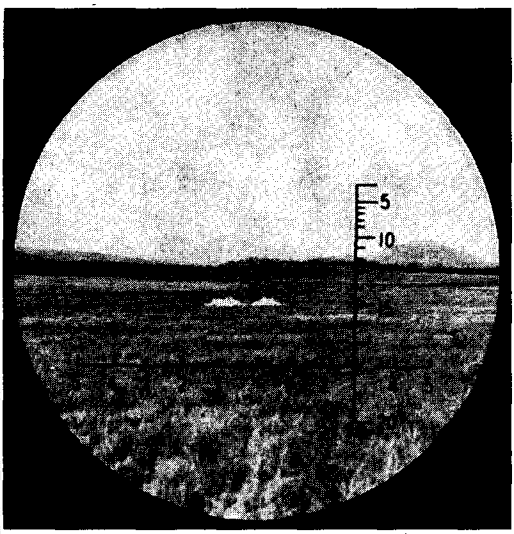
Remarks: *OT* distance from map = 3000 yards. From previous firing in vicinity of this target, observer has determined: (1) *S* = 30 yards, (2) Guns to left rear, and (3) Range-bracketing to be used. Adjustment is begun with platoon volleys. Observer decides to attack the target with time fire. First volley appears 30 mils left and 15 mils above base of target.

Observer to FDC: RIGHT 100, DOWN 25, REPEAT RANGE. FDC to Observer: *ON THE WAY.*		A	+

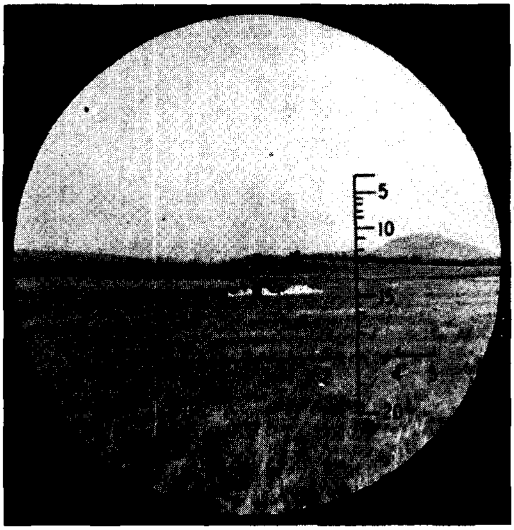
Remarks: Small deviation is ignored. Height of burst is now approximately 20 yards. Observer decides to make 400-yard initial range bound.

Messages, corrections, and commands	Results	Sensings	
		HB	RN
Observer to FDC: RIGHT 120, DROP 400. FDC to Observer: *ON THE WAY.*		A	—

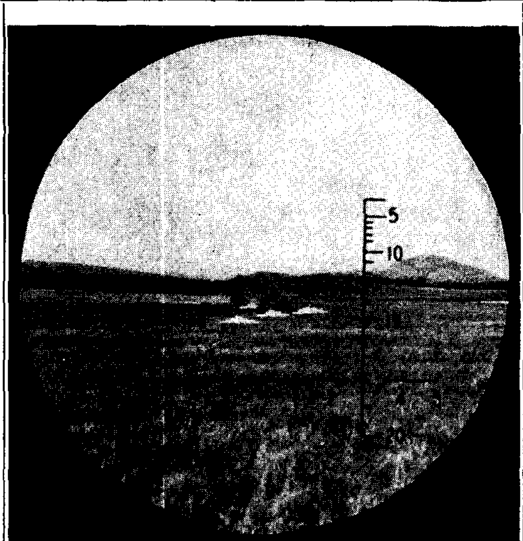
Remarks: Small deviation has persisted and should be corrected. Next shift: LEFT 30 to get on line + LEFT 60 to stay on line = LEFT 90.

Messages, corrections, and commands	Results	HB	RN
Observer to FDC: LEFT 90, ADD 200. FDC to Observer: *ON THE WAY.*		A	—

Remarks: Since battalion is to fire for effect, observer will obtain 100-yard bracket before calling for fire for effect.

Messages, corrections, and commands	Results	Sensings HB	Sensings RN
Observer to FDC: LEFT 30, ADD 100. FDC to Observer: *ON THE WAY.*		A	+

Remarks: Observer has established 100-yard bracket. Fire for effect is started at the center of the bracket.

Observer to FDC: RIGHT 15, DROP 50, FIRE FOR EFFECT. FDC to Observer: *BAKER FIRING FOR EFFECT.*			

Remarks: First volley in effect sensed, *mixed air, bracketing, deflection correct.* Remainder of fire for effect is observed and, if necessary, proper corrections are sent to FDC.

Messages, corrections, and commands	Results	Sensings	
		HB	RN
Observer considers fire for effect adequate; reports to FDC: MISSION ACCOMPLISHED, FIRE EFFECTIVE, MORTARS SILENCED.			

CHAPTER 4
CONDUCT OF FIRE BY DEFLECTION-BRACKETING PROCEDURE

Section I. GENERAL

118. EMPLOYMENT. Deflection-bracketing procedure is employed when the observed deviation between ranging rounds is *greater than 200 yards* (pars. 100 and 101). The observer is then considerably to one side of the *GT* line, and he can determine range error more accurately than deflection error. Deflection, therefore, is the controlling element.

119. DEFLECTION BOUNDS. a. First bounds. Deflection is changed *only* when a positive deflection sensing is obtained. After a round or salvo has been sensed positively, the first deflection bound is made large enough to bracket the target. A deflection bound of less than the bracket sought is not made until that bracket has been obtained. When the approximate amount of the deflection error cannot be estimated, the following may be used as a guide in determining the amount of the initial deflection bound.

(1) One *S*, for map data corrected.

(2) Two *S's* when using map data or when making a small shift from a previous target.

(3) Four *S's* when using data obtained by approximate methods. Normally, an initial bound greater than 400 yards is not required.

b. Bounds close to friendly troops. Fire close to friendly troops is opened with a deflection and a range which are surely safe. Deflection and range are then changed by bounds which are safe, until a deflection bracket or a correct deflection is obtained.

120. COMPUTATION OF RANGE FACTOR (*d*). a. In deflection-bracketing, bursts are brought to the *OT* line by range changes. To facilitate bringing off-line bursts to the *OT* line, a range factor (*d*), in mils, is employed by the observer. To determine this factor, the observer measures the deviation in mils between ranging rounds and di-

vides this angle by 4 to obtain the angular deviation caused by a 100-yard range change. The measured deviation of off-line bursts is divided by d to determine the number of 100-yard range bounds necessary to bring bursts to the OT line. When the observer is so close to the target that the use of angle-measuring instruments is impracticable, he is able to estimate the amount of range change necessary to place an off-line burst on the OT line, and the use of d is not necessary in this case. His estimation of range error is facilitated by the use of a "yardstick" established by ranging rounds or by other firing in the vicinity of his target.

b. The value of d may be determined also: (1) from firing tables; (2) approximately, by computation, using the formula $d = \frac{1/10T}{r}$ if T is less than 600 mils.

Section II. PROCEDURE

121. ADJUSTMENT, PRECISION FIRE. a. General. Adjustment is by single piece. Each round is sensed for deflection; for example, *deflection short,* or *deflection doubtful.* The object of adjustment is to obtain a *trial deflection.* The trial deflection is a deflection giving a target hit, or a deflection for the center of a 1-S bracket, or a deflection for the center of a bracket of 80 yards or less when S is greater than 80 yards. In order to obtain a trial deflection, an initial deflection bracket is sought; thereafter, the bracket is successively split until a trial deflection is obtained.

b. Ranging rounds. Unless the observer has previously determined the gun-target line, and the values of S (pars. 100 and 101) and d (par. 120) in the vicinity of the target, he orders ranging rounds fired and determines the factors. Factors are corrected promptly if determined by firing to be considerably in error.

c. To get on the line. When a burst cannot be sensed positively for deflection because of its deviation from the OT line, the amount of the deviation is measured in mils, and a range correction to place the next burst on the OT line is determined by dividing the deviation by d and multiplying by 100. For example: The observer senses *deflection doubtful* (80 mils right of the OT line); the d is 20; the piece is on the right. The range change to place the next burst on the line

is $80/20 \times 100 = 400$ yards. The observer sends: REPEAT DEFLECTION, ADD 400. It may be necessary to bracket the line with range changes to secure line shots. Because of dispersion and irregular ground, it often may be difficult to obtain successive line shots. Minor deviations should be ignored unless it is impossible to obtain sensings.

d. To stay on the line. (1) When a line shot is obtained, a range change of 100 yards is made for each 1-*S* deflection change in order to keep the burst on the *OT* line. When a burst off the *OT* line is sensed positively for deflection, the observer's range correction combines: (1) the range change to bring the off-line burst to the line, and (2) the range change to stay on the line when the deflection is changed. For example: The observer senses *deflection short* (burst is 60 mils left of the *OT* line); he decides to shift the deflection 2 *S's;* the *d* is 30; *S* is 70; the piece is on the left. A correction of ADD 200 ($60/30 \times 100$) places the burst on the line, and a range change of ADD 200 accompanies the deflection shift of LEFT 140; the net range correction is ADD 400 (ADD 200 to get on, ADD 200 to stay on). The observer sends: LEFT 140, ADD 400.

(2) When a deflection bracket is obtained, it is split. Thereafter, bursts are kept on or near the *OT* line by splitting the range bracket between sensed rounds. In the case of sensings obtained from bursts not on the *OT* line, the observer must modify this range bracket to bring off-line bursts to the line, and then split the resulting bracket. For example: during adjustment a line shot has been obtained and the observer sensed *deflection short;* he decides to shift the deflection 2 *S's; S* is 70; the piece is on the right. He commands RIGHT 140, ADD 200. The next burst is to the left of the *OT* line, but he obtains a sensing of *deflection over.* With the use of the range factor, he determines that a correction of DROP 40 would place the last burst on the *OT* line; therefore he would consider his range bracket to be 160 yards instead of 200 yards, and his next correction should be LEFT 70, DROP 120 (DROP 40 to get on the line, DROP 80 to split his effective range bracket of 160 yards). This correction should place the next burst on or very near the *OT* line. The brackets are narrowed until the trial deflection is determined.

122. FIRE FOR EFFECT, PRECISION FIRE. a. Starting fire for effect. Fire for effect is started when the trial deflection is determined. Each round is sensed for both range and deflection as in fire for effect in precision fire, range-bracketing (par. 110a). Range may be sensed by rule (par. 110b).

b. Direction. The deflection bracket is split successively until deflection is correct. Deflection is correct when a target hit is obtained, when a 10-yard deflection bracket (20-yard, for *GT* ranges greater than 10,000 yards) is split, or when a *deflection over* and a *deflection short* are obtained with the same deflection setting.

c. Range. Fire for effect is started with a range which will place the bursts on the *OT* line. Normally, the mean of ranges used when the trial deflection was established is satisfactory. Range adjustment continues as in range-bracketing precision, with the following exceptions:

(1) Rounds fired during adjustment normally are not considered in computing adjusted elevation. When the three rounds of the first half-group are all in the same sense, range is changed 50 yards in the proper direction, and a second half-group of three rounds is fired. The resulting range is not necessarily a range which established the trial deflection. The adjusted elevation is computed on this series of six rounds if both *overs* and *shorts* are obtained. When the rounds are all in the same sense, the range is changed 50 yards in the proper direction and additional half-groups of three rounds are fired until rounds in the opposite sense are obtained. The last six rounds fired are used to compute the adjusted elevation.

(2) Although a group of six rounds usually is sufficient to determine adjusted elevation in a registration, it may be necessary to continue fire by single rounds in order to complete the deflection adjustment. If six of these additional rounds are fired, advantage should be taken of them to improve the adjusted elevation.

d. Report of sensings. The observer reports sensings as in range-bracketing procedure (par. 110e).

123. ADJUSTMENT, AREA FIRE. a. General. Fire is begun with a parallel sheaf (or open sheaf, when appropriate), which is not changed during adjustment. Platoon or battery salvos, beginning from the flank away from the observer, are used. The object of adjustment is to enclose the target within a 100-yard (or smaller) deflection bracket, or to obtain target hits; this is accomplished by seeking an initial deflection bracket, and thereafter by successively splitting the bracket. Ranging rounds may be ordered if desired; they are fired by an interior piece. Quick, delay, time, or VT fuze may be used, depending upon the effect sought. Height of burst (in time fire) and deflection of the salvo as a whole are sensed; for example, *mixed air, deflection short*. If, during adjustment, a target hit is obtained or a salvo brackets the target for deflection, fire for effect is started immediately.

b. Range. The deviation of the burst center with respect to the *OT* line is determined. The burst center is then brought to and kept on the *OT* line by the same procedure as for a single burst in precision fire (pars. 121c and d).

c. Height of burst. Height of burst is corrected by the observer as in range-bracketing area fire (par. 111c.)

124. FIRE FOR EFFECT, AREA FIRE. a. Starting fire for effect. Fire for effect is started when a deflection bracket of 100 yards is split, or when target hits are obtained or a salvo brackets the target for deflection. A target hit or a salvo which brackets the target for deflection establishes the amount of the deflection error; a correction of this amount is made on entering fire for effect. In time fire, fire for effect is not started until the height of burst is correct, or until the observer is certain that his next correction for site will result in the correct height of burst. Height of burst (in time fire), range, and deflection are sensed for each volley as a whole; for example, *mixed air, over, deflection over.* When a correct deflection is established, deflection sensings may thereafter be omitted.

b. Fuze. The fuze is selected by the observer as prescribed in range-bracketing (par. 112b).

c. Direction. Deflection is improved when positive deflection sensings are obtained. Deflection is correct when rounds from the center pieces bracket the center of the target for deflection.

d. Distribution and height of burst. These are corrected, when necessary, in the same manner as prescribed in range-bracketing (pars. 112d and e).

e. Range. The deflection change for the initial volley is accompanied by a range change to center the fire on the target or area to be covered. During fire for effect, the observer makes necessary range corrections in the same manner as discussed in range-bracketing area fire (par. 112f).

f. Report of observer. Upon completion of fire for effect, the observer sends MISSION ACCOMPLISHED (if fire has been effective and sufficient) and reports the effect which he has observed; for example, MISSION ACCOMPLISHED, FIRE EFFECTIVE, INFANTRY DISPERSED.

125. FLANK OBSERVATION. As the *OT* line approaches the perpendicular to the *GT* line, the observer must modify the procedure described above for staying on the line. The true value of *S* increases very rapidly as the observer's position approaches the flank of the target; for example, when the observer approaches to within 300 mils of the perpendicular to the *GT* line, the value of *S* has increased to approximately 340 yards. Based upon firing, the observer may find it necessary to make very small range changes (or no range change at all) to keep bursts on the *OT* line when a deflection shift is made.

Section III. SUMMARY OF PRINCIPLES AND EXAMPLES, DEFLECTION-BRACKETING

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126. GENERAL. a. Employ deflection-bracketing procedure when the observed deviation between ranging rounds is *greater than 200 yards.*

b. Bring bursts to the *OT* line by making appropriate *range* corrections.

c. Keep bursts on the *OT* line by making a 100-yard range change for each 1-*S* deflection shift.

127. PRECISION FIRE. a. Adjustment. The object of adjustment is to determine the *trial deflection.* The trial deflection is a deflection giving a target hit, or a deflection for the center of a 1-*S* bracket, or a deflection for the center of a bracket of 80 yards or less when *S* is greater than 80 yards.

b. Fire for effect. (1) Start fire for effect at the trial deflection, and with a range correction which will place the bursts on the *OT* line. The rounds are fired singly or in half-groups of three.

(2) Based upon positive deflection sensings, improve the deflection until it is correct. Deflection is correct when a target hit is obtained, when a 10-yard deflection bracket (20-yard, for *GT* ranges greater than 10,000 yards) is split, or when *deflection over* and *deflection short* are obtained with the same deflection setting.

(3) Obtain and report to fire-direction center a group of six usable range sensings.

c. Time registration. Same as in summary of principles, range-bracketing (par. 115c).

128. AREA FIRE. a. Adjustment. (1) The object of adjustment is to enclose the target within a 100-yard (or smaller) deflection bracket.

(2) Select the type of ammunition which will be most effective against the target.

(3) Bring the burst center to the *OT* line by appropriate range corrections.

(4) In time fire, adjust the height of burst to 20 yards above the center of the target by correcting site. Fire for effect is not started until the height of burst is correct, or until the observer is certain that his next correction will result in the correct height of burst.

(5) If a target hit is obtained or a salvo brackets the target for deflection, start fire for effect immediately.

b. Fire for effect. (1) Start fire for effect when splitting a 100-yard (or smaller) deflection bracket, or when target hits are obtained or a salvo brackets the target for deflection.

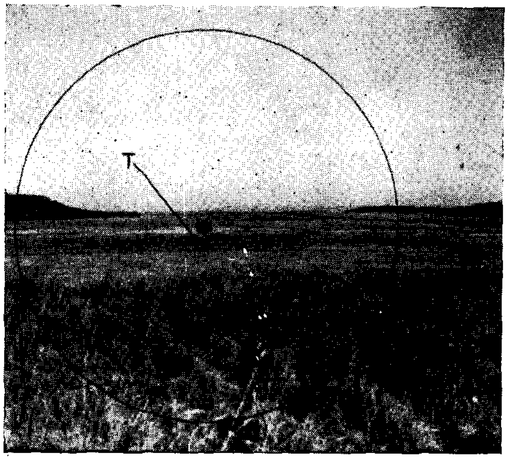
(2) Upon entering fire for effect, center the fire on the target or area to be covered by making an appropriate range change.

(3) Improve deflection when positive deflection sensings are obtained. Improve range when the preponderance of the fire is *over* or *short*. Deflection is correct when rounds from the center pieces bracket the center of the target for deflection.

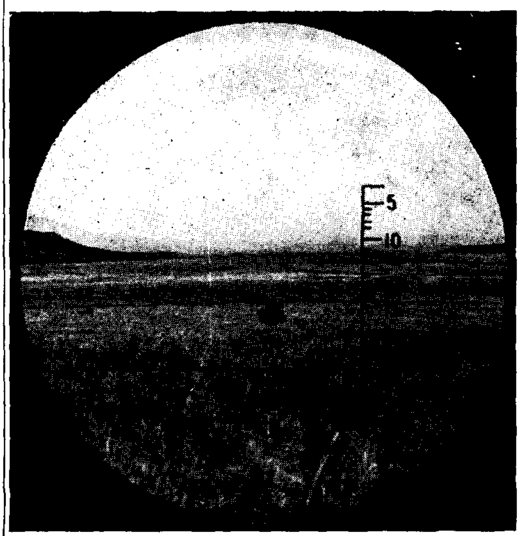
(4) If fire for effect is ineffective or insufficient make necessary corrections and command additional fire for effect.

(5) Upon completion of fire for effect, send MISSION ACCOMPLISHED and report the effect observed.

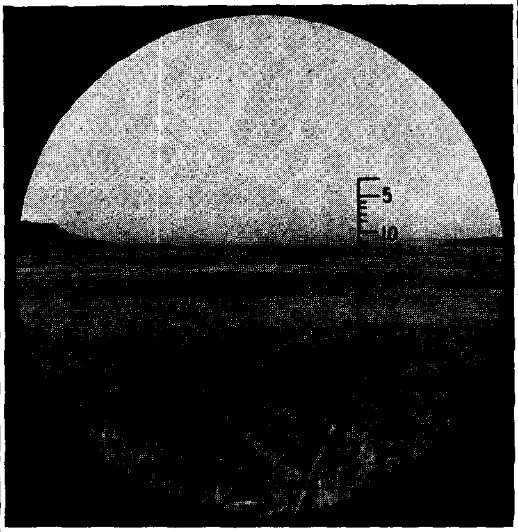
129. ILLUSTRATIVE EXAMPLES. a. Deflection-bracketing precision. Target, check point; mission, precision registration; materiel, 105-mm howitzer; ammunition, HE shell, quick fuze.

Messages, corrections, and commands	Results	Sensings RN	Sensings DF
Observer to FDC: FIRE MISSION, MARK CHECK POINT 1, FIRE RANGING ROUNDS, PRECISION REGISTRATION, WILL ADJUST. FDC to Observer: *ABLE,* *RANGING ROUNDS,* *FUZE QUICK,* *CHECK POINT 1,* *WHEN READY....* *ON THE WAY.*			+

Remarks: Deflection sensing obtained from second ranging round. *OT* distance from map = 2000 yards. With field glasses, observer measures 125 mils between ranging rounds. Observed deviation = 250 yards (125 × 2). *S* = 80 yards. Range factor = 30 mils (125/4). Deflection-bracketing to be used. Observer decides to make 4-*S* shift. Since first burst is 400 yards off line (in range) no range change will be required to place next burst on *OT* line when 4-*S* deflection shift is made.

Messages, corrections, and commands	Results	Sensings RN	Sensings DF
Observer to FDC: LEFT 320, REPEAT RANGE. FDC to Observer: *ON THE WAY.*			–

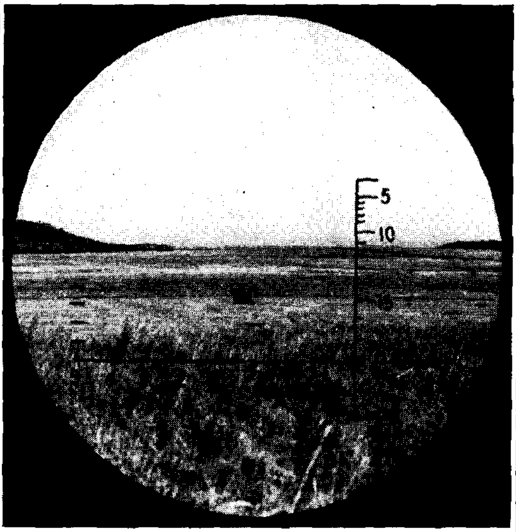
Remarks: *S* appears to be satisfactory.

Messages, corrections, and commands	Results	Sensings RN	Sensings DF
Observer to FDC: RIGHT 160, ADD 200. FDC to Observer: *ON THE WAY.*			?

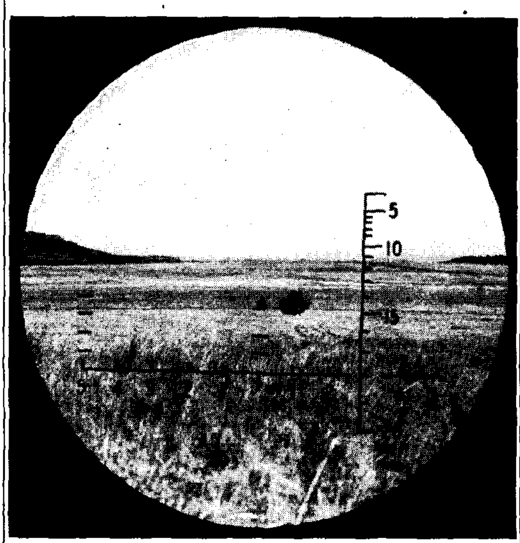
Remarks: To bring next burst to the *OT* line, change in range of 50 yards (15/30 × 100) is indicated.

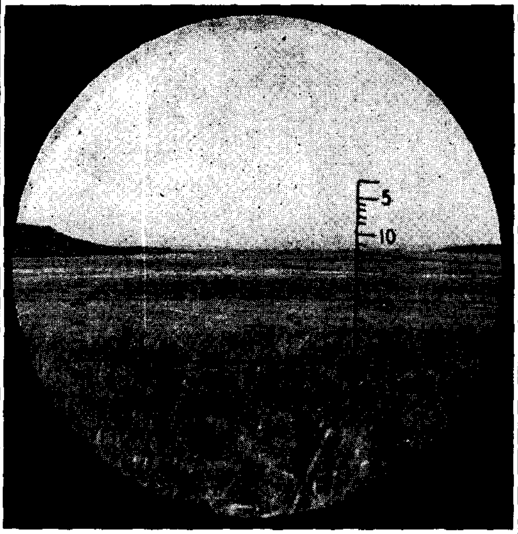
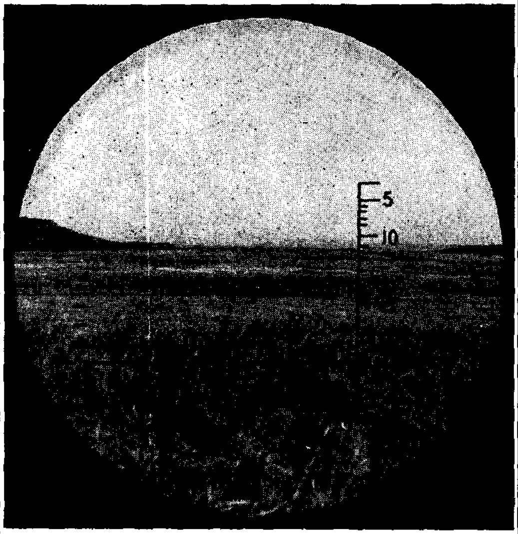
Messages, corrections, and commands	Results	RN	DF
Observer to FDC: REPEAT DEFLECTION, DROP 50. FDC to Observer: *ON THE WAY.*			+

Remarks: **Range bracket between sensed rounds is now 150 yards (200 - 50).**

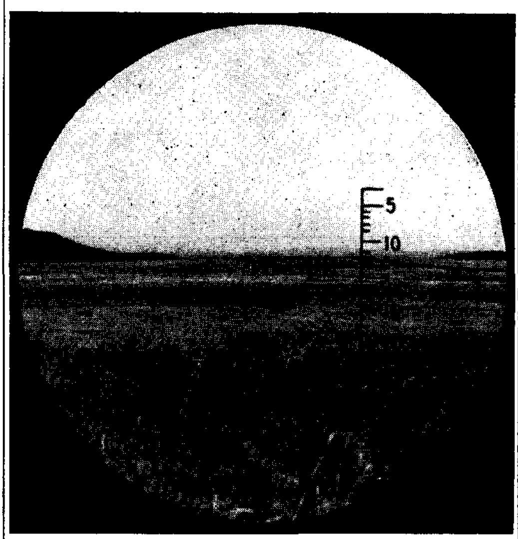
Messages, corrections, and commands	Results	Sensings	
		RN	DF
Observer to FDC: LEFT 80, DROP 75. FDC to Observer: *ON THE WAY.*			—

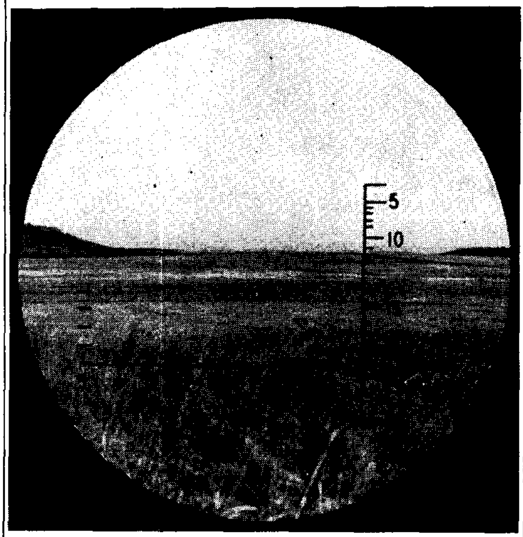
Remarks: Range bracket is now 75 yards; deflection bracket is 80 yards. With next split in deflection bracket, observer is ready to begin fire for effect.

Messages, corrections, and commands	Results	RN	DF
Observer to FDC: RIGHT 40, 3 ROUNDS, ADD 40. FDC to Observer: *ON THE WAY.*		—	?

Messages, corrections, and commands	Results	Sensings RN	Sensings DF
		+	?
		+	+

Messages, corrections, and commands	Results	Sensings	
		RN	DF
Observer to FDC: LEFT 20, REPEAT RANGE. FDC to Observer: *ON THE WAY.*		—	—

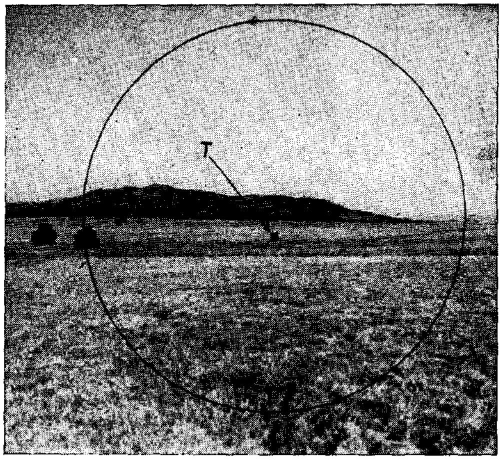
		—	?

Messages, corrections, and commands	Results	Sensings	
		RN	DF
		+	+

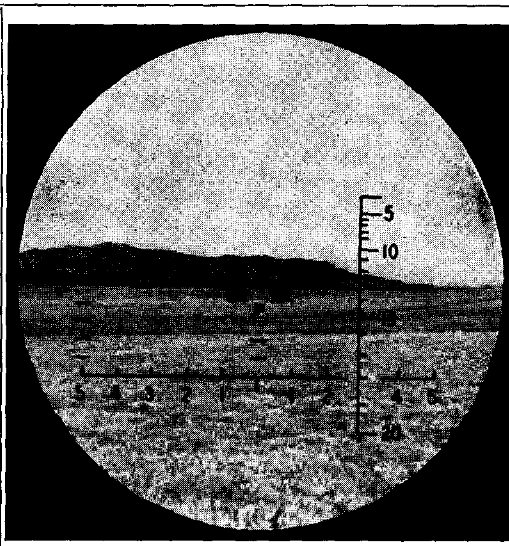
Remarks: Deflection is correct, since both *deflection over* and *deflection short* were obtained at the same deflection setting.

Observer to FDC: 3 OVERS, 3 SHORTS, REGISTRATION COMPLETE.			

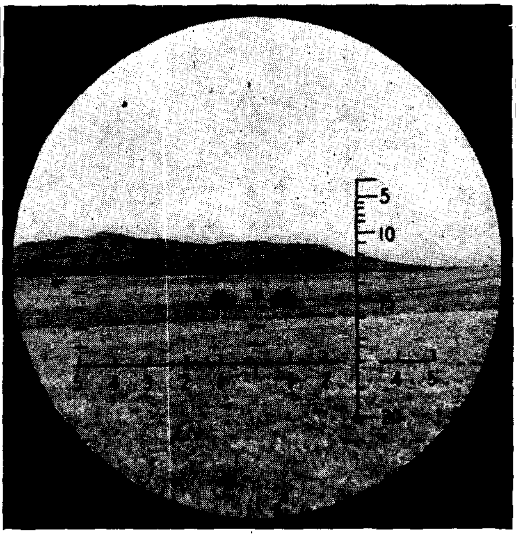
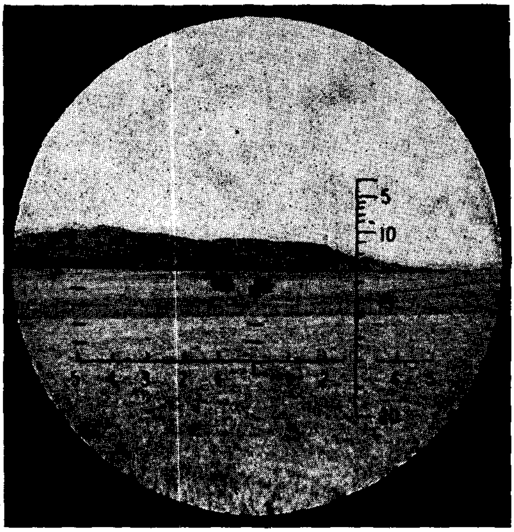
b. Deflection-bracketing area fire. Target, infantry reserves assembling in vicinity of an adjusting point; materiel, 105-mm howitzer; ammunition, HE shell (M48, M54, and M97 fuzes available).

Messages, corrections, and commands	Results	Sensings	
		RN	DF
Observer to FDC: FIRE MISSION, FROM CONCENTRA- TION 6, REPEAT DEFLECTION, UP 20, ADD 500, INFANTRY RESERVES ASSEMBLING, SALVO LEFT, VT FUZE IN EFFECT, WILL ADJUST. FDC to Observer: *BATTALION,* *CHARLIE,* *SALVO LEFT,* *FUZE QUICK,* *VT FUZE IN EFFECT,* *CONCENTRATION 27,* *3 VOLLEYS,* *1/2 C APART,* *WHEN READY....* *ON THE WAY.*			?

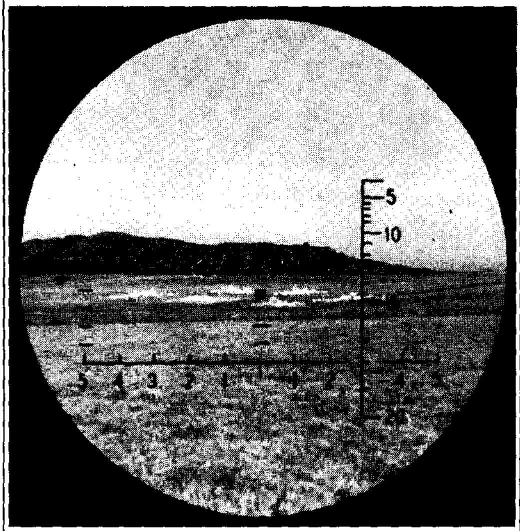
Remarks: *OT* distance from map = 1500 yards. From previous firing in the vicinity of this target, observer has determined: (1) $S = 100$ yards, (2) $d = 50$ mils, (3) Guns to left rear, and (4) Deflection-bracketing to be used. Adjustment is begun with platoon salvos. First salvo appears 75 mils left of target. To bring burst to line, ADD 150 ($75/50 \times 100$). FDC will give observer cavitized shell with quick fuze during adjustment.

Observer to FDC: REPEAT DEFLECTION, ADD 150. FDC to Observer: *ON THE WAY.*			+

Remarks: Observer believes that 2-*S* shift will give a deflection bracket.

Messages, corrections, and commands	Results	Sensings RN	Sensings DF
Observer to FDC: RIGHT 200, DROP 200. FDC to Observer: *ON THE WAY.*			−
Observer to FDC: LEFT 100, ADD 100. FDC to Observer: *ON THE WAY.*			+

Remarks: Observer can begin fire for effect with next split in deflection bracket. When observer orders fire for effect, FDC will order VT fuze and make compensating site correction.

Messages, corrections, and commands	Results	Sensings	
		RN	DF
Observer to FDC: RIGHT 50, DROP 50, FIRE FOR EFFECT. FDC to Observer: *CHARLIE FIRING FOR EFFECT.*			

Remarks: First volley is sensed *range correct, deflection correct.* Remainder of fire for effect is observed and, if necessary, proper corrections are sent to FDC.

Observer considers fire for effect adequate; reports to FDC: MISSION ACCOMPLISHED, FIRE EFFECTIVE, INFANTRY DISPERSED.			

CHAPTER 5
AIR OBSERVATION AND ADJUSTMENT OF NAVAL GUNFIRE

Section I. AIR OBSERVATION

130. GENERAL. a. An air observer may be a pilot or any other individual trained in air observation of artillery fire. The pilot of an aircraft normally should be furnished an observer and should not be called upon to pilot the aircraft and observe at the same time.

b. Appropriate missions for the air observer include:

(1) Adjustment on targets.

(2) Registration.

(3) Searching for targets.

(4) Surveillance of fire.

c. The normal means of communication between airplane and ground is two-way radiotelephone. Other means may be used when necessary.

d. The tactical employment of organic air observation is described in FM 20-100 (when published). Adjustment of artillery fire from high performance aircraft is discussed in section II, appendix VIII, FM 6–40.

131. PREARRANGEMENT. a. The pilot and air observer should be briefed daily. Routine matters to be covered include:

(1) Tactical situation (friendly and enemy).

(2) Location and zone of action of supported troops.

(3) Location of position areas and panel stations.

(4) Nature and location of known targets. Whenever possible, targets should be pointed out on an oblique photograph.

(5) Location of suspected targets and areas to be searched.

(6) Location and description of base point, check points, concentrations, and any special fires which have been planned.

(7) Flight restrictions.

(8) Details of communication.

(9) Code compass and code range, if any.

(10) Any maps, photomaps, or photos of value.

b. The observer should be assigned specific missions and should be given definite instructions before he leaves the ground.

c. Before taking off and immediately after becoming airborne, the observer should check radio communications.

132. PROCEDURE. a. General. The principle of *bracketing* the target for range (and for deflection in precision adjustments, or in any adjustment when the observer must remain well to the flank) applies in air observation as well as in ground observation. The air observer often adjusts fire at long observing ranges, and he may not be aided by observing instruments; obtaining proper brackets (as discussed in range-bracketing procedure) is essential to successful accomplishment of his mission. At short observing ranges, the observer's commanding observation permits him to make accurate estimations of range and deflection errors. At these short ranges, the experienced observer is able to place accurate area fire on the target without establishing brackets. For this technique, a definite "yardstick" on the ground must be established. Since the position of the observer with respect to the target is continually changing, it is vitally important for him to visualize the *GT* line on the ground throughout an adjustment. The *GT* line is easy to visualize when the observer flies above the position area or near the *GT* line.

b. Adjustment on targets. (1) Range-bracketing procedure is used, with the following modifications:

(*a*) Corrections are based upon observed errors from the *GT* line, and the observer need not coordinate range and deflection corrections in order to keep bursts on the *OT* line. Procedure during adjustment consists of determining the amount of deflection error, obtaining correct deflection by making the indicated shift (or by bracketing deflection, if necessary), and bracketing the target for range.

(*b*) The observer uses no factors.

(*c*) Normally, ranging rounds are not required. However, if the observer finds it necessary, he may order ranging rounds fired in order to establish the *GT* line and a "yardstick" on the ground.

(2) Estimation of the height of air bursts may prove difficult; however, the air observer can see the location of the effect with respect to the target much more readily than can the ground observer.

(3) As an aid to the observer and pilot, the fire-direction center may employ the warning, *SPLASH* (par. 104c). A time-of-flight signal is especially necessary when adjusting at long ranges, as it gives the pilot time to maneuver for a favorable position from which to observe the

burst. If the observer has difficulty in picking up the rounds, smoke shell or a high air burst may be used to locate the burst.

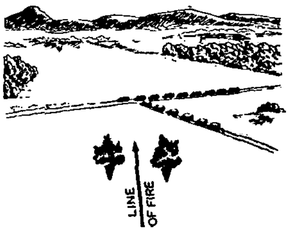
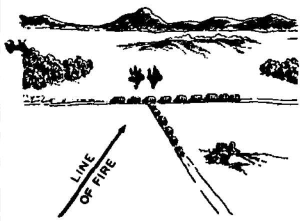
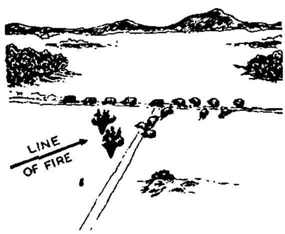
(4) To prevent losing the target when the airplane is turned, a well-defined reference point on the ground should be used.

c. Center of impact registration. (1) A single preliminary round is fired in the area where the center of impact is desired. If the burst is on or near some terrain feature identifiable on the map or air photo, the observer commands REPEAT DEFLECTION, SIX ROUNDS, REPEAT RANGE. Otherwise he moves the initial burst to a better location and fires six rounds.

(2) The observer marks the center of impact on a map or photo. He then may report the coordinates of the center of impact, drop the marked map or photo at the fire-direction center, or land and deliver the information.

d. Completion of a mission. Upon the completion of a mission, the fire-direction center may give the observer additional missions; or if other missions have been prearranged, the fire-direction center may send *FOLLOW INSTRUCTIONS.* Upon completion of all missions, the fire-direction center sends *NO FURTHER NEED OF YOU; GO HOME.* If the plane is forced down, the observer sends GOING HOME or FORCED TO LAND.

133. ILLUSTRATIVE EXAMPLE. While on a patrol mission, an air observer of a 155-mm howitzer battalion sees a traffic jam of enemy vehicles at a road junction. He identifies the road junction on his map and establishes radio communication with the battalion fire-direction center.

Messages, corrections, and commands	Results	Remarks
Observer to FDC: FIRE MISSION, KING GEORGE 3279, TRAFFIC JAM, 15 VEHICLES, WILL ADJUST. FDC to Observer: *BATTALION,* *ABLE,* *FUZE QUICK,* *CONCENTRATION 9,* *3 VOLLEYS,* *CENTER RANGE,* *WHEN READY....* *ON THE WAY.*		
Observer to FDC: REPEAT DEFLECTION, ADD 400. FDC to Observer: *ON THE WAY.*		
Observer to FDC: RIGHT 100, DROP 200. FDC to Observer: *ON THE WAY.*		
Observer to FDC: LEFT 50, ADD 100, FIRE FOR EFFECT. FDC to Observer: *ABLE FIRING FOR EFFECT....* *BAKER AND CHARLIE FIRING FOR EFFECT....* *ROUNDS COMPLETE, ABLE....* *ROUNDS COMPLETE, BAKER AND CHARLIE.*		FDC orders WP smoke mixed with the HE shell in fire for effect to add incendiary effect.
Observer to FDC: MISSION ACCOMPLISHED, FIRE EFFECTIVE, SEVERAL VEHICLES BURNING, OTHERS DISPERSED.		

Section II. ADJUSTMENT OF NAVAL GUNFIRE

134. GENERAL. a. The technique of employment of naval gunfire in support of ground operations is basically the same as for the employment of field artillery, but is subject to certain obvious advantages and limitations inherent in weapons fired from ships.

(1) The advantages are:

(*a*) Larger calibers and increased rates of fire.

(*b*) Mobility which enables selection of favorable lines of fire.

(*c*) The fact that the support received is without any compensating burden on ground force ammunition supply agencies.

(2) The disadvantages are:

(*a*) Navigational restrictions within firing sectors.

(*b*) Limited ammunition capacity of firing ships.

(*c*) Flat trajectories, except when reduced charges are provided.

(*d*) A new target must be designated by chart location unless it can be taken under fire immediately by shifting from the last target fired upon, or it must be designated with reference to a point clearly identified by line of sight from the firing ship.

(*e*) Radical turns or reversal of course by the firing ship may require a new adjustment or a delay in firing due to inherent lags of the fire control system.

(*f*) When the ship is firing while underway, the line of fire is constantly changing.

b. The adjustment of naval gunfire by ground observers follows the same basic technique as that prescribed for the adjustment of field artillery fire. Normally, communication is by radio, direct between the observer and the firing ship.

c. Ground adjustment of fire and establishment of the necessary communications are performed by the shore fire control party. This party consists of ground observers, ground communications personnel, and such naval personnel as may be assigned by the amphibious force commander.

d. After the artillery commander goes ashore, an artillery liaison officer familiar with the capabilities and limitations of naval gunfire should work with the naval gunnery officer aboard the amphibious force flagship controlling the naval gunfire. Similarly, a naval liaison officer should be at the ground fire-direction center whenever feasible.

135. SPECIAL CONSIDERATIONS, NAVAL GUNFIRE. a. Weapons available. (1) A variety of weapons is available for use in support of ground troops, dependent upon the type of firing ship which may be assigned. These weapons include 16-inch, 14-inch, 12-inch, 8-inch, 6-inch, and 5-inch guns on combatant ships, and 5-inch rockets and 4.2-inch chemical mortars from gunboats. 20-mm and 40-mm guns are available from all fire support ships, but range limitations restrict their use to targets near the shore line. Of the weapons listed, the rockets and mortars are used generally in prearranged fire on area targets, the 5-inch and 6-inch guns are used in close support of ground troops, and the larger calibers usually are directed at targets well within the enemy lines, and are adjusted by air observers. Any and all weapons, however, can be adjusted by ground observers.

(2) Guns of 5-inch caliber and larger are provided with bombardment ammunition which gives a fragmentation effect roughly comparable to field artillery projectiles of equivalent size. In addition, the armor-piercing projectiles normally used in fleet surface engagements are available. Illuminating shell is available for 5-inch and 6-inch guns; white phosphorus is available only for 5″/38 guns (the standard destroyer weapon). A reduced charge (1200 f/s) has been developed for use with the 5″/38 gun, and provides a trajectory roughly equivalent to that given by the use of charge 4 in the 105-mm Howitzer, M2.

(3) Fuze types vary with different calibers and projectiles, but generally include quick, delay, mechanical time, and VT.

b. Pattern. (1) Normally, supporting fire is delivered with four guns firing with a converged sheaf.

(2) With bombardment ammunition fired with reduced charge, the range pattern of a salvo fired from a single ship varies from approximately 75 to 125 yards for the 5-inch gun to 500 yards for the 16-inch gun. When the salvo is converged on a point target, the deflection pattern is roughly 10 percent of the range pattern. With the 5-inch shell, fragmentation is such as to give effective coverage of an area approximately 70 yards in width by 125 yards in depth. (The navy term "salvo" corresponds to the field artillery term "volley.")

136. PRINCIPLES GOVERNING OBSERVER. In order to obtain an accurate and rapid adjustment on a target, the observer must employ the following principles when adjusting naval gunfire.

a. Give a brief but complete target description to enable the naval gunnery officer to make the best possible selection of projectile and fuze.

b. Obtain accurate initial data.

c. Make bold changes.

d. Bracket the target for both range and deflection.

e. Act only on positive sensings.

f. Conserve ammunition.

g. Shoot fast.

h. Visualize or shoot in the *GT* line; bear in mind that normally the ship is moving.

i. Be alert to make compensating corrections if the center of impact tends to creep due to motion of the firing ship or lag in fire control mechanism.

j. Observe closely the effectiveness of the fire for effect and make corrections when indicated.

137. PREARRANGEMENT. Rehearsals and training between observers and fire support ships should precede each operation. The observer must be furnished the necessary maps or map substitutes to be used in the designation of targets. He must also be furnished and be familiar with the grid system and codes that are to be used. The observer must understand the plan of communication between himself and the firing ship.

138. INITIAL FIRE MESSAGE. In the initial fire message sent to the firing ship, the observer includes the elements listed in paragraph 103. The following are the minor differences which must be borne in mind when adjusting naval gunfire.

a. Targets may be designated by one of the following methods:

(1) By grid coordinates.

(2) By the 200-yard target squares of the World Polyconic Grid.

(3) By a shift from the last target fired upon.

(4) By a shift from a known point (a prominent point visible from the sea or, more usually, the radar beacon position established by the shore fire control party).

b. It is mandatory that the observer send the classification of fire (CLOSE or DEEP). The classification of fire permits the naval gunnery officer to decide the caliber of guns to be used.

c. The observer may include (SO MANY) GUNS FOR ADJUSTMENT. If he does not include this element, the naval gunnery officer makes the decision as to the number of guns to use for adjustment.

139. INFORMATION SENT TO OBSERVER. a. The supporting ship informs the observer whether it is able to fire the mission.

b. When the ship fires, the observer is notified *ON THE WAY*. Five seconds before the round strikes or bursts, the warning *SPLASH* is transmitted.

c. To signify completion of fire for effect, the firing ship transmits *ROUNDS COMPLETE*.

d. When the observer has sent AT MY COMMAND, the firing ship transmits *READY* to indicate that the ship is ready to fire.

140. ADJUSTMENT OF FIRE. a. General. (1) Usually adjustment is conducted using one or two guns. Additional guns are brought in for fire for effect. The number of guns which can be employed is dependent upon the type of ship and varies from four to six 5-inch guns on a destroyer to nine 16-inch and ten 5-inch guns on the newer battleships.

(2) The principles of conduct of fire by area fire methods (chs. 3 and 4) are employed. If the target can be seen from the ship, the ship may take over the adjustment after it has positively identified the target. In this manner, adjustment can be conducted most rapidly; the ground observer performs surveillance of fire. Destruction missions may be fired if the target can be observed from the ship.

b. GT line. Determining the *GT* line and keeping it constantly in mind as the ship maneuvers offshore is a problem peculiar to the adjustment of naval gunfire by ground observation. The Navy does not employ ranging rounds, but any of the following methods of determining the *GT* line may be used:

(1) The observer may fire two rounds or salvos at different ranges, and observe the direction of the change on the ground.

(2) If the ship has been directed to operate within a given sector, its general location will be known to the observer.

(3) If no sector has been designated, the observer may request the location of the ship, either by grid coordinates or by the range and bearing from any easily identified object.

(4) The direction of the ship from the observer may be determined by use of a radar beacon such as is normally supplied to shore fire control parties. The observer may request the bearing to the beacon or the bearing of the line of fire determined by the firing ship, and thus anticipate the line of fire on the ground.

c. Factors. The value of S (and the range factor, where appropriate) may be determined by commanding two rounds or salvos fired a known distance apart (400 or 800 yards), determining the observed deviation, and proceeding as discussed in paragraphs 101 and 120. The observer must take into account the fact that since his guns may be continually moving, his factors will change somewhat between rounds.

d. Deflection and range corrections. During adjustment these corrections are determined in the same manner and are given in the same sequence as in conduct of field artillery fire.

e. Distribution. Normally, the sheaf used in firing is converged and is not changed by the observer.

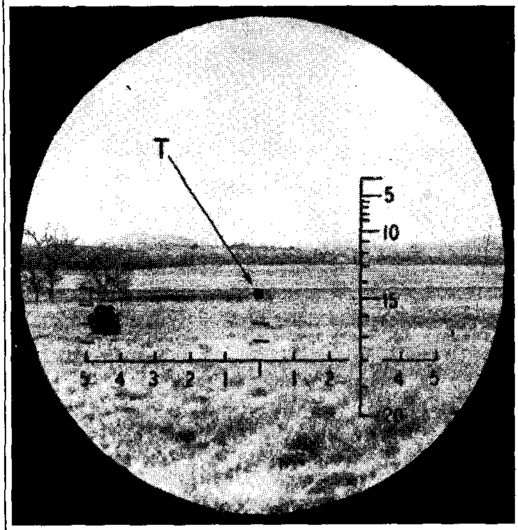
f. Height of burst. When time fire is used, height of burst is adjusted (in the same manner as in field artillery fire) so that bursts occur from 15 to 20 yards above the target.

g. Fire for effect. (1) Fire for effect is started when a suitable adjustment has been obtained, i.e., when deflection and range (and height of burst in time fire) are correct, or when effective fire will result with the next split in bracket. When range-bracketing procedure is used, the observer should not enter fire for effect until he has split a 100-yard range bracket, or has obtained a bracketing salvo or a target hit; in deflection-bracketing, fire for effect is started when the trial deflection (par. 121) is determined.

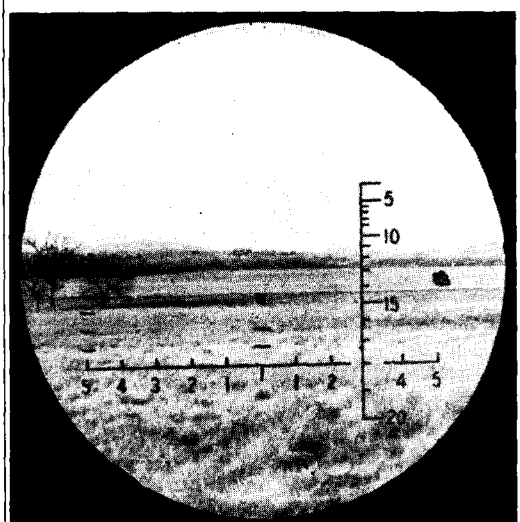
(2) If fire for effect is accurate and sufficient, the observer sends MISSION ACCOMPLISHED, and reports the effect observed. If necessary, the observer may send any appropriate corrections determined from the initial fire for effect, and command REPEAT FIRE FOR EFFECT.

(3) If the target covers an area greater than the pattern of the ship's fire for effect, the entire area is covered by successive shifts; for example, the observer might command LEFT 70, REPEAT RANGE, REPEAT FIRE FOR EFFECT.

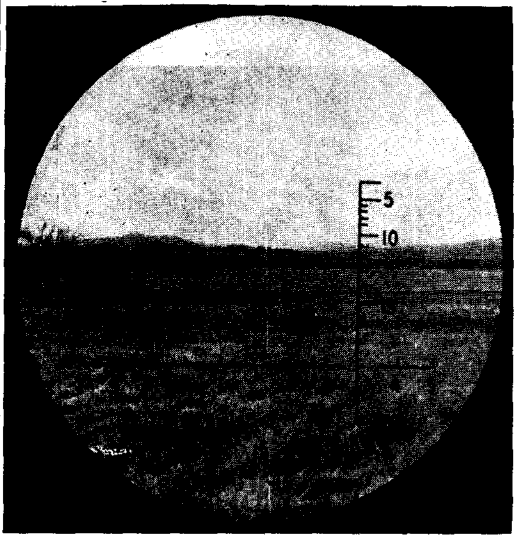
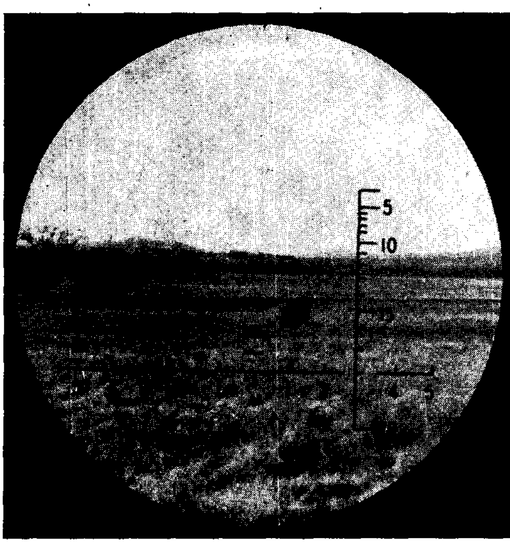
141. ILLUSTRATIVE EXAMPLE. Target, infantry weapons in the vicinity of a terrain feature; mission, neutralization; materiel, 5-inch gun.

Messages, corrections, and commands	Results	Sensings RN	Sensings DF
Observer to Ship: FIRE MISSION, 1760 KING, INFANTRY WEAPONS, DEEP, WILL ADJUST. Ship to Observer: (Initial fire message repeated for verification.) *ON THE WAY....* *SPLASH.*		?	

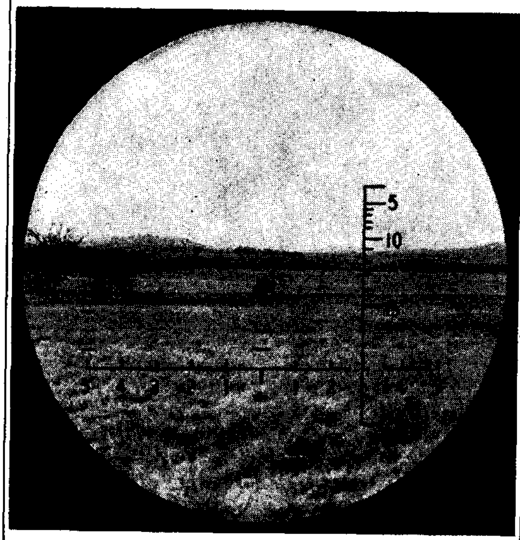
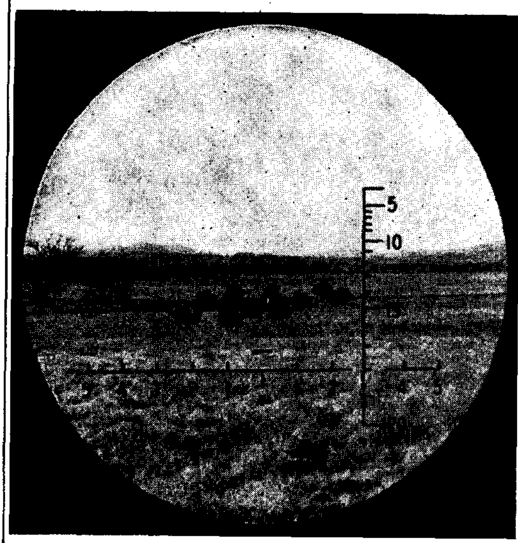
Remarks: *OT* distance from map = 1600 yards. Observer decides to make large range change to shoot in *GT* line and determine factors. Since the observer does not know the direction of fire, this round must be sensed *doubtful.*

Messages, corrections, and commands	Results	Sensings RN	Sensings DF
Observer to Ship: REPEAT DEFLECTION, ADD 800. Ship to Observer: *ON THE WAY....* *SPLASH.*		+	

Remarks: *GT* line is shot in, and it is now apparent that the first round was *short* for range; thus the observer has established an 800-yard range bracket. Deviation between the first two rounds is determined to be 160 yards (100 × 1.6). *S* of 20 (160 ÷ 8) will be used initially. Ship is on observer's left. Range-bracketing will be used. To get on line - LEFT 90 (55 × 1.6). To stay on line when the range is decreased 400 yards - RIGHT 80 (4 *S's*). Net shift. LEFT 10.

Messages, corrections, and commands	Results	Sensings RN	Sensings DF
Observer to Ship: LEFT 10, DROP 400. Ship to Observer: *ON THE WAY. . . .* *SPLASH.*		—	
Observer to ship: LEFT 40, ADD 200. Ship to Observer: *ON THE WAY. . . .* *SPLASH.*		—	

Remarks: Observer must correct for deviation. Next deflection correction: LEFT 20 (12×1.6) to get on line + LEFT 20 to stay on = LEFT 40.

Messages, corrections, and commands	Results	Sensings	
		RN	DF
Observer to Ship: LEFT 40, ADD 100. Ship to Observer: *ON THE WAY....* *SPLASH.*		+	
Observer to Ship: RIGHT 10, DROP 50, FIRE FOR EFFECT. Ship to Observer: *FIRING FOR EFFECT....* *ROUNDS COMPLETE.*			

Remarks: Pattern covers the desired area and weapons are silenced. Repeat of fire for effect is not indicated.

Messages, corrections, and commands	Results	Sensings	
		RN	DF
Observer to Ship: MISSION ACCOMPLISHED, FIRE EFFECTIVE, WEAPONS SILENCED.			

CHAPTER 6
MISCELLANEOUS OBSERVED FIRES

Section I. DIRECT LAYING

142. GENERAL. When the target can be seen through the sight of the piece, direct laying is employed against the following: moving hostile vehicles, such as tanks; enemy personnel attacking the battery position; or other targets which can be seen from the gun position. Occasionally direct laying may be employed in attacking such stationary targets as fortifications; however, assault-fire technique usually is used for such missions. Normally, direct laying is conducted by individual piece by the piece commander. For a detailed discussion of direct laying, see FM 6–140 and the pertinent field manual on the service of the piece.

143. CONDUCT OF FIRE. Each piece is adjusted individually on the target. Direction is taken from the target itself. Adjustment is made by placing the point of burst on the desired part of the target (for high velocity and flat trajectory weapons) or by bracketing the target as in range-bracketing procedure (for low velocity weapons).

Section II. ASSAULT FIRE

144. GENERAL. An artillery piece may be used for the destruction of caves, pillboxes, or other fixed fortifications. Any weapon of caliber less than 155 millimeters is uneconomical for this purpose. The weapon must be emplaced at such a range as to make possible the obtaining of successive hits on the same portion of the target. Generally, this range should not exceed 2,500 to 3,000 yards, except for the 240-mm howitzer which can be effectively employed up to 4,000 yards. Pin-point accuracy is vital. Because of their maneuverability and the rapidity with which they may be emplaced and displaced, self-propelled weapons are much better suited to this type of mission than are towed weapons.

145. AMMUNITION. a. Projectiles. HE shell is used for the destruction of most fortifications. However, if the material to be penetrated is hard rock or heavy reinforced concrete, deeper penetration can be obtained with the use of armor-piercing (AP) projectiles fired at the highest striking velocity attainable. Since armor-piercing shell has little or no explosive filler it tends to make a deep crater of small diameter. In order to widen this crater and clear away rubble when armor-piercing shell is being used, the observer should order a round of HE shell with concrete-piercing fuze (M78) or M51 fuze quick fired every fourth or fifth round. Armor-piercing or high-explosive antitank (HE,AT) shell should be used against steel.

b. Fuzes. Concrete-piercing fuzes are normally used in the destruction of fortifications; therefore, the nondelay concrete-piercing fuze is used in adjustment since it has a small ballistic difference from fuzes of the M51 series. Ordinary M51 delay fuzes are used only when concrete-piercing fuzes are not available, or they may be used to cut a channel through a parapet or through an earth covering. In such a case the M51 fuze (set for superquick) is used for adjustment.

c. Charges. The highest charge which will clear the mask and reach the desired point on the fortification is used.

146. ADJUSTMENT. Adjustment is made using modified range-bracketing procedure. Each piece has an observer who should be as close to the target as possible in order to be able to make estimates of range and deflection errors to the nearest yard. When the bursts are near the target, the observer usually can estimate vertical error more accurately than he can estimate range error; therefore, after bursts have been brought close to the target, the observer makes corrections of *site* rather than *range*. Corrections are given in yards and are converted into fire commands at the gun position. Sample corrections are: RIGHT 4, UP 5, REPEAT RANGE; LEFT 1, DOWN 2, REPEAT RANGE; RIGHT ½, REPEAT RANGE.

147. FIRE FOR EFFECT. Fire for effect is started when the point of impact has been brought to the desired part of the target. Rounds are fired singly to permit the observer to make necessary corrections or changes in ammunition between rounds. Fire for effect is continued until the target has been destroyed.

148. LAYING THE PIECE. a. At the gun, deflection changes are made to the nearest mil until a 1-mil deflection bracket is obtained; further changes are made to the nearest ¼ mil. A deflection board attached

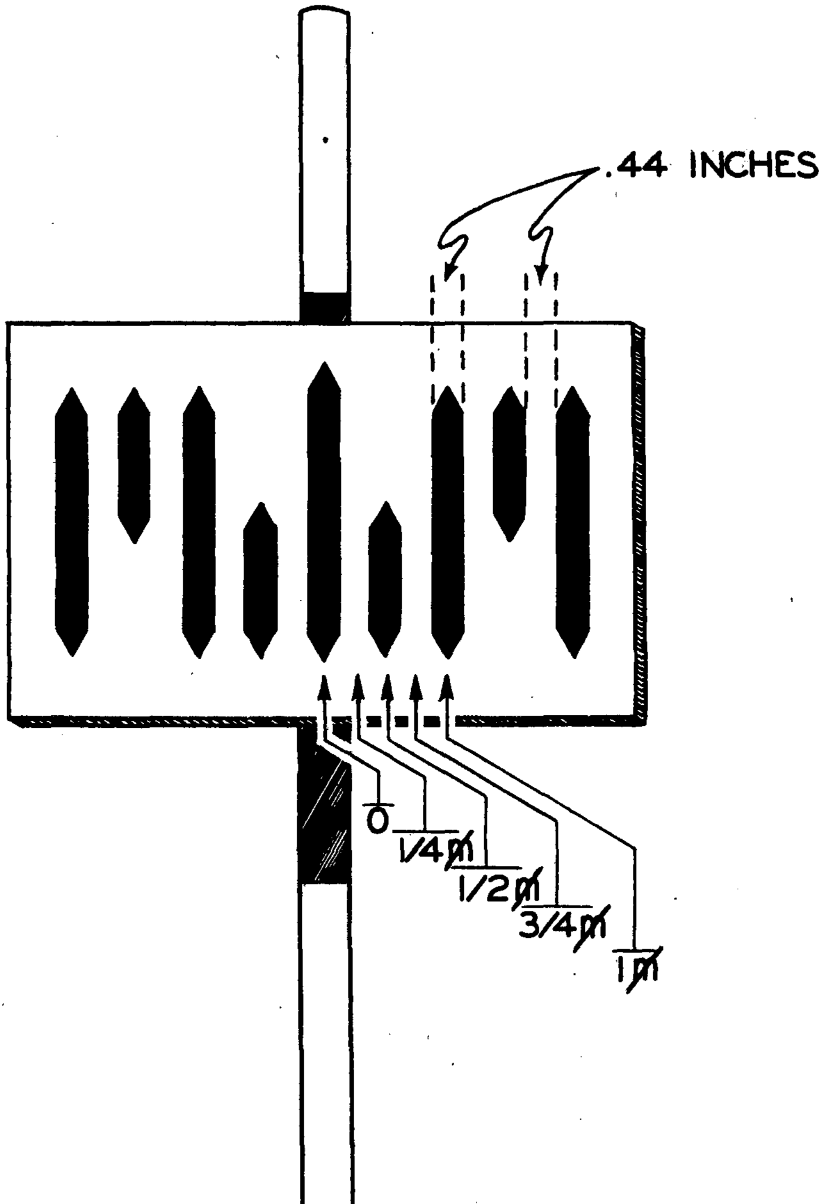


Figure 36. Deflection board.

to the aiming stakes is used for this purpose. The deflection board illustrated in figure 36 enables the gunner to make deflection changes of 1/4 mil. The black and white bands are 1/4 mil in width when viewed through the sight of the piece at a distance of 50 yards. The gunner lays on the desired portion of the board by centering the crosshair of the sight upon a black (white) band on the board. To move 1/4 mil, he moves the line of sight (by traversing the piece in the proper direction) so that the adjacent white (black) band is covered; to move 1/2 mil, the crosshair is moved two bands, etc.

b. Changes in elevation are made to the nearest one-tenth mil. The gunner's quadrant is used.

149. ILLUSTRATIVE EXAMPLE. Target, reinforced concrete pillbox, visible side banked with 10 feet of earth; mission, destruction; materiel, 8-inch howitzer, self-propelled; ammunition, HE shell with M51 and M78 fuzes, and projectile, armor-piercing.

Observer's messages, corrections, and commands	Sensings	Remarks
FIRE MISSION, MARK CENTER HILL 1090, PILLBOX, MAXIMUM CHARGE, FUZE QUICK, WILL ADJUST.	?, 50L	
RIGHT 50, REPEAT RANGE.	+, 10R	Round was close enough to target that vertical deviation could be estimated.
LEFT 10, DOWN 5, REPEAT RANGE.	T	Round struck earth bank. Obsr places succeeding rounds to cut channel through earth to face of concrete wall.
LEFT 2, DOWN 1, FUZE DELAY, REPEAT RANGE.	T	After several rounds are fired, channel through dirt is cleared and the concrete wall is exposed.
REPEAT DEFLECTION, UP 1, FUZE CONCRETE-PIERCING DELAY, REPEAT RANGE.	T	Burst raised 1 yard arbitrarily to correct for difference in trajectory caused by concrete-piercing fuze. Rounds are fired singly. Obsr may order AP or HE,AT Interspersed with one round in four or five of HE shell with concrete-piercing fuze. This will hasten penetration. As penetration continues, Obsr orders an occasional round of HE with quick fuze to clear rubble. Fire for effect is continued until penetration is accomplished and the pillbox destroyed.
MISSION ACCOMPLISHED, PILLBOX DESTROYED.		

Section III. HIGH-ANGLE FIRE

150. GENERAL FEATURES. a. Fire delivered at elevations greater than the elevation for maximum range is called *high-angle fire*. Its use is appropriate when fire is being conducted into or out of deep defilade such as is found in jungle, sharply eroded terrain, and cities, or over high terrain features near friendly troops.

b. When high-angle fire is desired, the observer includes in his initial fire message, HIGH-ANGLE FIRE. Adjustment is conducted using either range-bracketing or deflection-bracketing procedure, whichever is appropriate. From the point of view of the observer, high-angle fire has the following characteristics, in contrast to fire at normal elevations:

(1) Depending upon the weapon used, there is little overlap in the ranges reached by the various charges, and in some cases there may be dead space between charges. During an adjustment, it may be necessary for the fire-direction center to change from one charge to another, unless the observer has given the *accurate* location of the target initially.

(2) With a given charge and deflection setting, high-angle rounds fired at varying elevations will fall approximately along a straight line. Because of the large drift resulting from high-angle fire, this line will not coincide with the actual *GT* line, and is therefore called the *effective GT line* (figs. 37 and 38). Since drift increases as the range decreases, the guns appear to be farther to the right than their actual location. The effective target offset varies from the actual target offset by approximately 100 mils for all weapons and charges. A compensating shift for the change in drift is not necessary to keep the burst on the *OT* line when changing ranges within a charge. The factor *S* is determined for the effective target offset and makes this compensation.

(3) Because of the steep angle of fall, ricochet fire is not possible. The long time of flight prevents the use of time fire. The steep angle of fall gives the maximum effectiveness in all directions of the side spray of quick-fuzed shell. With VT fuze this effect is combined with a much lower point of burst than is normally obtained with the VT fuze. This makes high-angle fire less effective against personnel in trenches but more effective against exposed targets, when compared with fire delivered at normal elevations.

(4) In observed fires, the site may be ignored unless the difference in altitude between gun and target is very large.

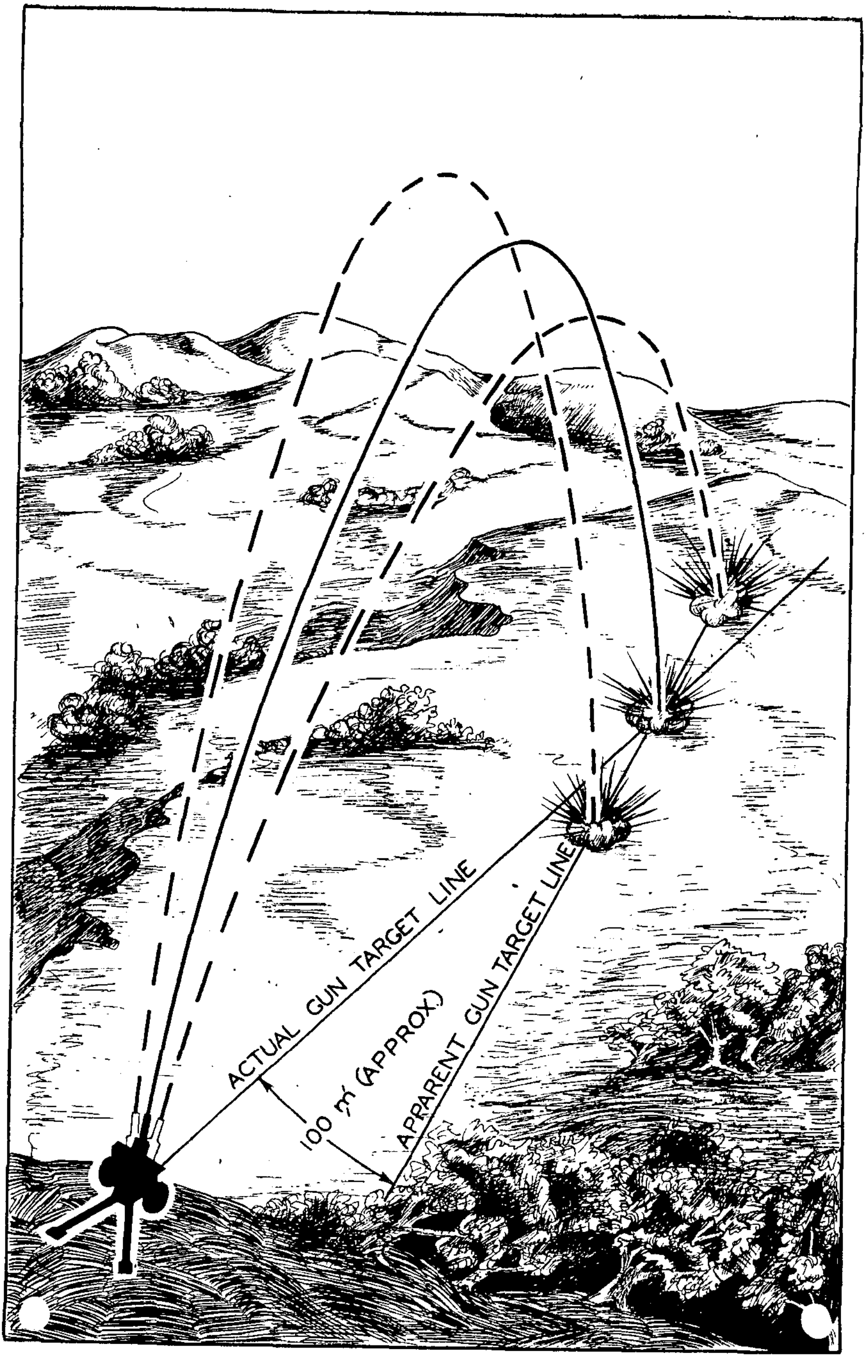


Figure 37. Drift effect, changes in elevation only, high-angle fire.

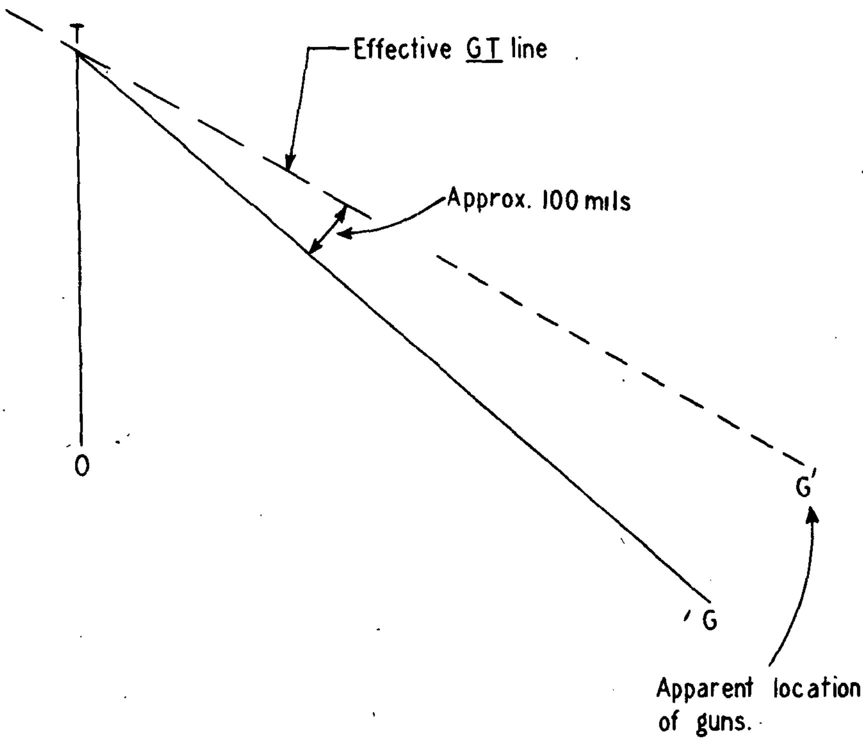


Figure 38. Effect of drift in high-angle fire.

c. It is necessary for fire-direction center to take into account the following characteristics of high-angle fire:

(1) An increase in elevation decreases the range to the point of impact.

(2) An increase in angle of site requires a decrease in quadrant elevation. The complementary angle-of-site factor is greater than unity, has a sign opposite to that of the angle of site, and when algebraically added to the computed angle of site, results in a small site of the opposite sign. The high-angle scales on the graphical firing table give the site (angle of site plus complementary angle of site). The sign of the site is opposite to the sign of the angle of site to the target. (See TM 9-524.)

(3) High-angle fire involves extremely high maximum ordinates and correspondingly long times of flight. Also, small changes in range cause relatively large changes in maximum ordinate and time of flight. These conditions make corrections to be applied in unobserved transfers somewhat unreliable and prevent definite fixing of transfer limits. Consequently, every effort should be made to obtain observation.

(4) Drift is very great and increases with an increase in time of flight. Thus in high-angle fire drift increases as the range is decreased for any one charge. In changing from a lower to a higher charge at a given range, the drift increases; in changing from a higher to a lower charge at a given range, the drift decreases. When changing charges during an adjustment, a shift is made to compensate for the difference in drift. The shift may be obtained rapidly by determining the difference in drift from the graphical firing table. This shift is to the left when changing to a higher charge, and to the right when changing to a lower charge.

(5) Time of flight is so great that adjustment is slow. Identification of rounds may be difficult unless the observer considers time of flight. The observer must be given either the time of flight when he is notified *ON THE WAY*, or the warning *SPLASH* five seconds prior to impact.

(6) Conduct of high-angle fire is greatly facilitated by the use of the graphical firing table rather than the tabular firing table.

Section IV. CONDUCT OF FIRE WITH CHEMICAL SHELL

151. GAS SHELL. a. General. Gas shell is fired within restrictions laid down by higher authority. Velocity and direction of the wind are always considered, especially when friendly troops may be endangered. Data for firing gas shell should be the most accurate obtainable. If possible, registrations and adjustments are made with the type of shell which is to be used in fire for effect. When sensings cannot be made using gas shell, adjustment may be conducted with HE; compensation is made for the difference in ballistic properties before fire for effect is started. The quick fuze is used for gas shell.

b. Nonpersistent gas. Surprise and rapid building up of an effective concentration are essential elements in the success of an attack with nonpersistent gas. Surprise is attained by means of a transfer or by an adjustment on an auxiliary target. An effective concentration is built up rapidly by the employment of a large number of pieces of large caliber, and by rapid firing for a short time.

c. Persistent gas. When well distributed on vegetation, materiel, and ground, a persistent gas is most effective against personnel. To obtain this effect, a given amount of gas delivered with light weapons is preferable to the same amount delivered by medium and heavy weapons.

152. SMOKE SHELL (fig. 39). a. General. Smoke is used for screening enemy observation; for prearranged signals; and, when necessary, as an aid in the adjustment of fire. Use of smoke for screening must be coordinated with higher authority. To build and maintain a smoke screen, fire must be adjusted. The proper location of bursts relative to the target depends upon direction and velocity of the wind, volume and density of smoke produced by each burst, and rate of production of smoke. This location is determined by observation of bursts during adjustment. Adjustment is conducted with a single piece. The rate of fire necessary to maintain the screen depends upon the width of front to be screened, the direction and velocity of the wind, and the volume and density of smoke produced by each burst. The fire of a single piece, the continuous fire of several pieces, or volley fire may be used. When smoke is used to prevent enemy observation of the operations of friendly troops, the observer who is adjusting the fire should be near the troops whose operations are to be concealed.

b. Base ejection type smoke shell. (1) Hexachlorethane (HC), the smoke-producing agent in this type of shell, burns with relatively little heat and does not "pillar." Since it is hygroscopic, it is made more effective by rain and mist.

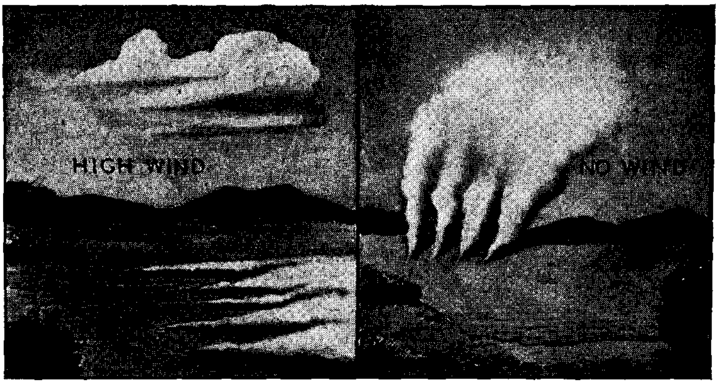
(2) When the objective is to build and maintain a smoke screen, fire must be observed to be effective. The lowest practicable propelling charge is used. Time fuze is used with a time setting that surely will cause the smoke charges to be ejected before impact. The setting used for time of burning should be from one to two seconds less than that for a zero height of burst. Fuze M67, without booster, can be used with 155-mm shell to obtain a time of burning greater than 25 seconds.

(3) The burning qualities of the smoke charges are as follows:

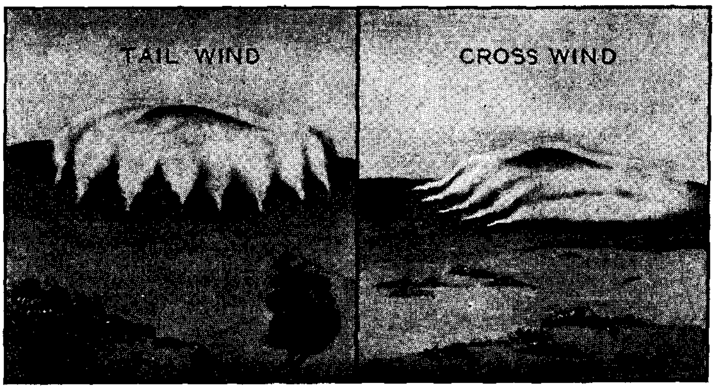
	105-mm	*155-mm*
Time to emit effective cloud	1 minute	30 seconds
Time to reach maximum effectiveness.....	2 minutes	1 minute
Total time of burning	3 minutes	4 minutes

(4) If a wind is parallel to the front to be screened, the spacing of points of fall may be as great as 400 yards. If a wind is perpendicular to the front to be screened, the spacing may be as close as 30 yards. A rough guide for computation of ammunition requirements for a screen for each point of fall is as follows:

Wind velocity (Miles per hour)	Rate of fire (Rounds per minute) *105-mm*	*155-mm*
3	1	½
10	1½	¾
15	2	1



WIND SPEED



WIND DIRECTION

CLIMATIC CONDITIONS

Figure 39. Weather conditions affecting smoke.

(5) Since the smoke is emitted from the canisters in thin streams which travel an appreciable distance before billowing out enough to form an effective screen, points of fall *must* be well upwind from the target.

c. White phosphorus shell. The smoke-producing agent of white phosphorus (WP) burns rapidly and is inclined to "pillar." Quick fuze is used to build and maintain a smoke screen. The ammunition requirements for building and maintaining a smoke screen with this type of shell are greater than those for the base ejection type. Casualty and incendiary effect are produced by white phosphorus.

Section V. CONDUCT OF FIRE WITH ILLUMINATING SHELL

153. USES FOR ILLUMINATING SHELL. Illuminating shell can be used to advantage for any of the following specific purposes and in any other situation where illumination is needed.

a. Illuminating areas of suspected enemy movement, attack, or counterattack.

b. Surveillance of fires at night.

c. Night adjustment and observation of the effect of artillery fire.

d. Harassing enemy positions and installations.

e. Furnishing direction to infantry for attacks or patrols. (Place flares well in advance of our troops to avoid illuminating them.)

f. Night photography.

154. DESCRIPTION OF ILLUMINATING SHELL. The projectile is a hollow, base-ejection type shell. A cylindrical flare attached to a cotton parachute is inclosed within the projectile. A time fuze, without booster, ignites the black powder charge in the nose of the shell. The explosion blows off the base plate and expels the flare and parachute. The flare attains full illumination about ten seconds after being ejected.

155. ADJUSTMENT OF ILLUMINATION. a. The following tables give characteristics of the illuminating shell M118, 155-mm howitzer:

Proper height of burst	700 yards
Time of burning	60 seconds
Rate of fire for continuous illumination	1 round every 30 seconds
Optimum distance between adjacent bursts for volley fire	700 yards

b. The proper height of burst is that which will allow the flare to stop burning just before it strikes the ground.

c. The correct quadrant elevation to place the point of burst at the proper height for a given range, under normal conditions, is given in the appropriate firing table or graphical firing table.

d. The correct relative position of flare and target depends upon the terrain. The point of burst should be such as to give the most effective illumination on the target and to insure that the final travel of the flare is not between the observer and the target. In a strong wind this will necessitate placing the point of burst some distance from the target so that the flare will drift to the desired location near the target. Generally, the position of the flare should be slightly to one flank of the target and at about the same range. If the target is on a forward slope, the flare should be on the flank and at a slightly shorter range. For a precision adjustment on a very prominent target, better visibility may be obtained by placing the flare beyond the target in order to silhouette the target. In this case care must be taken that the adjustment is made on the target and not on its shadow.

e. A strong wind may decrease the time interval necessary between rounds when firing for continuous illumination.

f. It is best to observe in the illuminated area from a location as close as possible to this area. In the event that the observer cannot get close to the illuminated area, good observation can be obtained from ranges up to 2,500 yards. Observation on prominent targets can be obtained at ranges up to 4,000 yards.

g. The size of the area effectively illuminated depends upon the observing distance. For one 155-mm shell it is about 400 yards in diameter, when observing from medium ranges. Two rounds bursting simultaneously at about the same place produce a better lighted area and may be used when observing conditions are poor because of haze, smoke, dust, or long observing range.

h. Two rounds fired with pieces converged, set to burst simultaneously at 700 yards difference in range, will give good observation for range and will reduce the shadows resulting from a single flare. Such a pair of rounds will permit much better observation of the terrain than two single rounds fired at the same point. In searching an area, sufficient rounds, properly located to cover the area, should be fired simultaneously. Firing four rounds simultaneously, each round on the corner of a square 700 yards on a side, will illuminate an area more than 1,000 yards square with no shadows or dark areas.

i. Illuminating shell may be adjusted over a point of known range and may be transferred to other points at known ranges. However, the effect of the wind on the flare may reduce transfer limits considerably. A correction to the range obtained from the adjustment is applied as a flat correction. This flat correction to the range is adopted rather than a percentage (*K*) correction because the effect of the wind upon the travel of the flare after it explodes is probably more important than the change in range to the point of burst caused by the weather. The refinement of adjusting the illuminating shell closer than 100 or 200 yards to the target usually is not justified. An adjustment must take into account the direction and velocity of the wind around the point of burst.

j. Any changes in the height of burst should be made in multiples of 30 yards. The slight variation in the time of burning of the individual flares renders useless any closer adjustment of the height of burst. When the point of burst is too high the change required is estimated from the position of the flare when it dies out. When the point of burst is too low the change required is estimated from the length of time the flare burned on the ground.

k. When firing illuminating shell with the 155-mm howitzer no charge greater than charge 5 should be used.

156. NIGHT ADJUSTMENT OF ARTILLERY. a. When the tactical situation requires, night adjustment of artillery fire and surveillance of fires can be accomplished by employing illuminating shell. If an operation includes the use of "artificial moonlight" or if the observer has control of searchlights for direct illumination, he may adjust artillery fire at night by making use of these types of illumination. However, "artificial moonlight" usually affords very limited observation since the light is diffused over a wide area and may not be controlled by the observer. Searchlights used for direct illumination may be readily neutralized by enemy fire if they remain in operation for more than a few seconds at a time. With the use of illuminating shell these disadvantages are overcome since the observer can obtain satisfactory and continuous illumination of the target area and has direct control of this illumination through normal channels.

b. When an adjustment mission is to be fired during darkness with the aid of illuminating shell, the observer indicates in his initial fire message that he will adjust the illuminating shell. For example, he might send:

FIRE MISSION
KING MIKE 7236 (to indicate point of burst of the illumination)
TANKS AND INFANTRY ASSEMBLING
ONE GUN (to indicate that one-gun illumination is desired)
ILLUMINATION
WILL ADJUST.

c. The observer adjusts the illuminating shell to the desired location; then, with continuous illumination, he adjusts the remaining pieces on his target using the appropriate projectile and fuze. During the adjustment of the illumination, normally fired by a flank piece, the other pieces of the battery follow all deflection commands. When the illuminating shell has been adjusted satisfactorily, the observer designates the location of his target with respect to the burst center of the illumination and begins the adjustment of HE shell. For example:

CONTINUOUS ILLUMINATION
FROM ILLUMINATION
LEFT 100
SHELL HE
DROP 200.

He may, if desired, specify the length of time for the illumination to continue.

d. When the command CONTINUOUS ILLUMINATION is given, no further changes in data are made for firing illuminating shell unless called for by the observer. The piece used to fire the illuminating shell continues to fire at the rate of one round each 30 seconds (for the 155-mm howitzer).

e. The HE adjusting piece is (pieces are) fired at the deflection and range indicated by the observer's commands. The executive determines from the illuminating shell firing table the range at which the illuminating shell is being fired, then determines from the HE shell firing table the elevation for the target corresponding to the range indicated by the observer's commands.

f. When the piece firing the illuminating shell is from a different battery than the one firing HE, the illumination is adjusted and then initial data is sent to the battery firing HE. If the location of the target is known with sufficient accuracy, data may be sent to both batteries initially. If the situation warrants, the battery firing HE may be laid for direction by sighting on the flare.

Section VI. COMBINED OBSERVATION

157. GENERAL. a. Conduct of fire is termed *combined* when there are two or more observers placed so that their observing lines intersect at an appreciable angle. From the combined information given by the observers, the amount and direction of the error of each round may be found. Combined observation is useful for registering with a minimum number of rounds; for adjustment when deviations, but not sensings, can be reported, as in night adjustments; and for accurate surveillance of scheduled missions. The most serious limitation is the difficulty of coordination between two or more observers, especially in regard to timing, communication, and target designation.

b. Targets or adjusting points may be designated by an observer or by the officer conducting fire, by giving grid or polar coordinates, by designating a reference point and an instrument reading and vertical angle, by giving a description of the target, or by designating the target by reference to nearby objects.

c. When the targets have not been designated in advance, both observers must have communication with the officer conducting fire. When observers are to designate targets, direct communication between observers is desirable. Immediate communication is desirable but not essential for center of impact or high-burst registrations.

d. When the reference point cannot be seen after dark, a nearby point must be established during daylight on which to orient the instrument after dark, in order that the observer will be able to report instrument readings at night.

158. CENTER OF IMPACT AND HIGH-BURST REGISTRATION. a. An accurate firing chart is required. The horizontal locations of observers, piece, and reference point must be known. The relative altitudes of the piece and observers must be known.

b. The observers are given instrument readings to the expected point of burst. A single piece fires a group of rounds, preferably six, with the same piece settings. These settings are the *adjusted data* for computation of corrections. Each observer reports the instrument reading to each burst, and reports the vertical angle to the burst.

c. The center of impact of the group of rounds is plotted by intersection, using the mean instrument readings. The altitude of the center of impact is computed from the average of the altitudes obtained

from the vertical readings of each observer. The angle of site is computed. *Map data* are determined from the plotted location of the center of impact.

d. A high-burst registration is identical in principle to a center of impact registration. It differs in the following particulars:

(1) A high-burst registration is fired with time fuze, and cannot be used if time shell is not available, or if limiting ranges of time shell prevent reaching the desired area. A center of impact registration is fired with impact fuzes, and is not subject to these limitations.

(2) High-burst registrations usually are easier to observe, since the air bursts are conspicuous, whereas impact bursts often are lost to one or both observers, especially in rugged terrain. At night, the air burst is a well defined flash, easy to pick up in the reticle, whereas impact bursts often are a diffused glow.

(3) Time correction may be determined from a high-burst registration, but not from a center of impact registration.

(4) In a high-burst registration, the battery executive can be used as the axial observer under certain conditions. However, when the angle of site to the burst center exceeds approximately 50 mils above the ground level of the target area, errors in elevation corrections will be obtained, especially when the maximum range for each charge is approached. These errors are eliminated by the method prescribed in e below.

(5) There is no limitation to the area in which high-burst registration can be used except the limits imposed by the time of burning of the fuze. It can provide corrections for that part of the terrain concealed to our observation, whereas a center of impact registration can be conducted only on undefiladed terrain.

e. When the battery executive is to act as axial observer in a high-burst registration, large differences in site with resultant error are avoided by the following procedure: A round is fired high enough in the air so that the battery executive can observe it above the mask. He determines the instrument reading to the burst. (More than one round may be required to secure an accurate instrument reading.) This instrument reading fixes the axial ray for plotting the burst center. Site is then decreased and succeeding rounds are fired at as nearly as possible the site of the target area. The lateral observer reports the instrument reading and the vertical angle to each burst. The mean instrument reading of the lateral observer fixes the lateral ray for plotting the burst center. The altitude of the burst center is computed from the mean vertical angle measured by the lateral observer.

159. ADJUSTMENT ON TARGETS. a. If observation posts have been located on the firing chart and instrument directions established, observers report instrument readings or deviations. The location of each burst center is plotted by intersection, errors are determined, and appropriate changes in data are made. Fire for effect is commenced when a target hit or a burst near the target is obtained. The use of an auxiliary target is appropriate in area fire; under these conditions, however, transfers with surveillance will be more economical of time and ammunition.

b. When one observer is axial and the other is lateral, no chart is required for the adjustment of fire. The axial observer conducts the fire, using range-bracketing procedure. He adjusts deflection promptly. Thereafter, the lateral observer senses range by rule. If the range factor (par. 120) is known, the approximate amount of range error can be determined.

c. When both observers are lateral and no chart is available, one observer may conduct the fire by deflection-bracketing procedure using the other observer's reports to supplement his sensings.

d. To facilitate the adjustment when both observers are in a lateral position, the S-3 may conduct the fire, drawing an "X" to represent the lines of sight of the left and right observers, and a line to represent the *GT* line if known. On the sketch he plots the sensings roughly and makes appropriate changes in data.

e. The methods set forth in a, b, and d above are applicable at night. If the relative locations of observers and guns are unknown and if deviations are sensed in yards or mils from the *OT* lines, the method set forth in d above will give good results. The *OT* line is recorded on targets discovered during daylight by all observers. At night the illuminated crosshairs of an observing instrument are placed on the enemy gun flash, and site and instrument readings are recorded if adjustment is not initiated at once. As an expedient, direction to a flash may be materialized on the ground by a piece of white tape or two stakes. Adjustment of fire at night is made with quick fuze.

160. SURVEILLANCE. Maximum effective fire results when the target location, registration, and surveillance of fire are all performed by the same observers. Fire for effect is used initially when warranted by the accuracy of target location and registration. The officer conducting fire notifies each observer of the number of batteries firing, and the method of firing for effect. Each observer reports the deviation or instrument reading of the mass of the initial volleys.

161. ILLUSTRATIVE EXAMPLES. a. Mission, high-burst registration; materiel, 105-mm howitzer; ammunition, shell HE, charge 5, fuze M54.

Both observers are lateral. Each instrument has been zeroed on a reference point in the target area. Orientation for observers: *RIGHT OBSERVER, INSTRUMENT READING 425, VERTICAL ANGLE +20; LEFT OBSERVER, INSTRUMENT READING 6280, VERTICAL ANGLE +10.*

Initial commands (FDC to battery): NO. 2 ADJ, SH HE, CH 5, TIME 19.9, BDR 215, SI 315, NO. 2, 1 RD,

Rd No.	Commands	Instrument reading		Vertical angle		Remarks
		Left obsr	Right obsr	Left obsr	Right obsr	
1	EL 350	*GRAZE*	*LOST*	*+5*		Site raised to secure air bursts within view of right observer.
2	UP 20, 350	*6253*	*424*	*+23*	*+20*	Not counted in total.
3	350	*6243*	*421*	*+18*	*+16*	
4	350	*6257*	*422*	*+15*	*+12*	
5	350	*6258*	*421*	*+16*	*+14*	
6	350	*6264*	*421*	*+15*	*+13*	
7	350	*6258*	*420*	*+17*	*+14*	
8	350	*6252*	*422*	*+15*	*+14*	6 rounds for effect.
Average		6255	421	+16	+14	

The officer conducting fire decides that six rounds are sufficient for the registration. The observers and battery are notified, *END OF MISSION.* Rounds 3 through 8 which are used to determine average readings for plotting the burst center were fired at TIME 19.9, BDR 215, SI 335, EL 350. These are the adjusted data. The horizontal location of the burst center is plotted on the firing chart by intersection. Angle of site is computed as +19 mils by using the mil relation formula, the vertical angles reported by the left and right observers, the relative altitudes of each observer and the piece, and the distances scaled on the chart to determine the mean altitude of the burst center. Complementary angle of site ($+.16 \times +19\text{⧸h} = 3\text{⧸h}$) is added to the angle of site ($+19\text{⧸h}$), giving a site of $+22\text{⧸h}$. A shift of BDR 224 and a range of 5820 yards to the burst center are scaled to this plotted location on the firing chart. These are the map data. Corrections are

determined by fire-direction center. The deflection correction is determined to be *left 9.* The adjusted elevation is determined as follows:

Elevation fired	350
Site fired	+35
Quadrant elevation fired	385
Site to burst center	− (+22)
Adjusted elevation	363

Graphical firing table settings: *Charge 5, fuze M54, range 5820, adjusted elevation 363, adjusted time 19.9.*

b. Mission, night registration on a check point; materiel, 105-mm howitzer; ammunition, HE shell, charge 5; map shift to the check point is BDL 313, map range is 4900 yards (elevation 282₥), map site is +2₥ (SI 302).

Observation: One lateral observer on left, and the battery executive. Lateral observer's exact position is not known, but he has an instrument laid on the check point. Executive has recorded instrument direction following registration on the base point.

No. 2 is the base piece.

Initial commands (FDC to battery): INSTRUMENT DIRECTION L 313, NO. 2 ADJ, SH HE, CH 5, TIME 16.4, BDL 313, SI 302, NO. 2, 1 RD, EL 282.

The battery executive lays his instrument on the indicated instrument direction, and commands:

NO. 2 ADJ, SH HE, CH 5, TIME 16.4, BDL 313, SI 480, NO. 2, 1 RD, EL 282, FIRE. (He gave an arbitrary increase in site to cause the round to burst above the mask in order that he might observe it from the gun position; the executive orders succeeding rounds fired with the site commanded by FDC, i.e., SI 302.)

He observes this round 5 mils right of the line of sighting, gives the command LEFT 5 to the adjusting piece, and reports to fire-direction center: *DEVIATION, 5 MILS RIGHT; CORRECTED.*

The lateral observer is notified to continue the adjustment. He senses range by rule, and sends to fire-direction center corrections of range only.

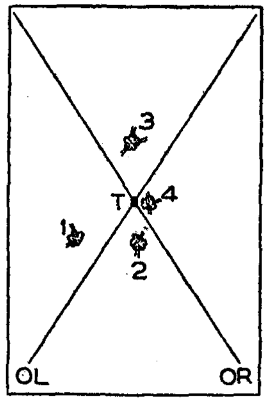
Rd No.	Observer's corrections and commands	Sensings		Remarks
		Rn	Dev (mils)	
1				This was the round observed by the executive.
2	REPEAT DEFLECTION, FUZE QUICK, M54, REPEAT RANGE	–	13 R	Obsr decides to make initial range change of 200 yds.
3	REPEAT DEFLECTION, ADD 200	+	11 L	
4	REPEAT DEFLECTION, DROP 100	+	3 L	
5	REPEAT DEFLECTION, 3 ROUNDS, DROP 50	–	10 R	
6		–	2 R	
7		–	7 R	
8	REPEAT DEFLECTION, 2 ROUNDS, ADD 50	+	2 L	
9		+	5 L	
	3 OVERS, 3 SHORTS, REGISTRATION COMPLETE			FDC computes adjusted elevation and determines corrections as for any other registration.

If a time registration is required, the adjustment proceeds as prescribed in range-bracketing procedure, time registration (par. 110h).

c. Target, machine gun emplaced in pillbox and discovered by gun flashes at night; mission, destruction; materiel, 155-mm howitzer; ammunition, HE shell, charge 7, fuze concrete-piercing.

Two observers in front lines report target. Their positions are known only approximately. S-3 decides to conduct fire from deviations reported by the observers.

OL to S-3: FIRE MISSION, FROM BASE POINT, RIGHT 200, DROP 1000, HEAVY MACHINE GUN IN PILLBOX FIRING, DESTRUCTION, MAXIMUM CHARGE, FUZE CONCRETE-PIERCING, WILL ADJUST.



OR to S-3: CAN OBSERVE TARGET.

S-3 to observers: *ABLE, ONE PIECE, FUZE CONCRETE-PIERCING NONDELAY, CONCENTRATION 5, WILL CONDUCT FIRE, REPORT DEVIATIONS, WAIT.*

Initial commands (S-3 to battery): NO. 2 ADJ, SH HE, CH 7, FUZE CONCRETE-PIERCING NONDELAY, BDR 40, SI 300, NO. 2, 1 RD,

Rd No.	Commands (S-3 to Btry)	Reports of deviation		Remarks
		Left obsr	Right obsr	
1	EL 160	*100 L*	*200 L*	Sensings in mils from *OT* lines.
2	R 30, 160	*80 R*	*50 L*	Short.
3	170	*100 L*	*50 R*	Over; with range change only, sensings established definitely that OL is left of *GT* line and OR is on right.
4	165	*5 R*	*8 R*	Deviation sensing by both observers is close to the *OT* line; range is approximately correct; deflection right.
5	FUZE CONCRETE-PIERCING DELAY, L 5, 3 RDS, 165	*LINE*	*4 L*	Short, deflection left.
6		*3 L*	*4 L*	Doubtful, deflection left.
7		*10 L*	*LINE*	Over, deflection left.
8	R 3, 4 RDS, 165	*LOST*	*LOST*	Mine action or dud.
9		*3 R*	*LINE*	Short, deflect on right.
10		*LINE*	*LINE*	Target, deflection correct.
11		*2 R*	*2 L*	Short, deflection doubtful.
12	1 RD, 165	*2 R*	*1 L*	Short, deflection doubtful. Preponderance of three shorts. $3/12 \times 5 = +1$. Adjusted elevation: $165+1 = 166$
	6 RDS, 166			Fire is continued until mission is accomplished.

Section VII. CONDUCT OF FIRE WITH SOUND AND FLASH OBSERVATION

162. GENERAL. a. Appropriate missions. The technique employed by field artillery observation battalions is presented in FM 6-120. The observation battalion may be used for the accurate location of targets, for the adjustment of fire, and for registration at greater distances and under more difficult conditions than is possible with organic firing battalion equipment and technique. Location of hostile artillery by sound and flash ranging, and registration of friendly artillery by flash ranging, are particularly appropriate missions. Adjustments by sound and flash ranging are time-consuming, and while thus engaged observation units are taken away from their primary mission of locating targets. Sound ranging is not recommended for registration purposes. Sound ranging units cannot determine height of burst in time fire adjustments.

b. Target designation. Coordinates normally are used to designate targets in conduct of fire by observation units. In the absence of a coordinate system common to both the observation and artillery units, corrections may be made in relation to a base point, check point, or reference point. Altitudes are furnished if known. Observation personnel estimate the degree of accuracy of target location, evaluate the missions, and send WILL ADJUST if conditions warrant adjustment. After a target is designated by a sound unit, adjustment should follow immediately to reduce errors from changes in atmospheric conditions. To eliminate errors, adjustment should be made wherever possible by the same unit that reported target location.

163. REGISTRATION WITH FLASH RANGING. a. Initial data. The artillery unit furnishes the coordinates and altitude of the registration point in order that observers may orient their instruments to bring the first burst into the fields of view. Time of flight and *ON THE WAY* are announced by the firing unit to assist the observers in identifying the burst. A code time of flight should be used with radio communication. Firing data with latest corrections are given to the adjusting battery.

b. Center of impact. The flash ranging unit may request one or more orienting rounds fired AT MY COMMAND in order to orient observers and to assure positive identification of the initial rounds. It commands FIRE for the initial orienting rounds and may specify

the interval between rounds to be fired in the group for registration. The firing unit will specify the number of rounds (preferably six). *ON THE WAY* should be reported for each round. When the registration is completed, the coordinates and altitude of the center of impact are reported to the firing battalion. Additional rounds may be requested if the desired results are not obtained because of erratic readings, or lost or erratic rounds.

c. High burst. High-burst registration normally is used when impact bursts would not be visible to observers. Groups of rounds are fired as in b above, and the coordinates and altitude of the burst center are reported.

164. CONDUCT OF FIRE. a. Adjustment. (1) FLASH RANGING. Adjustment is conducted by a single piece firing groups of two or more rounds with the best data available. The firing unit reports time of flight, direction of fire, and method of fire for effect. *ON THE WAY* is given for each round. The flash ranging unit makes necessary corrections to bring bursts to the target. The adjustment is continued until the flashing ranging unit estimates that the next shift will obtain effect on the target, at which time the next correction is followed by the command FIRE FOR EFFECT. If surprise fire is desired and the target is located accurately, preliminary adjustment of fire on the target itself may be entirely eliminated. It is the function of the firing battalion to determine whether prior registration is necessary and to choose the point for registration with benefit of recommendations from the flash ranging unit. The facilities of the flash ranging unit may be employed also to conduct precision adjustments for destruction.

(2) SOUND RANGING. Adjustment is conducted by firing groups of two or more rounds in order to obtain a center of impact, thereby decreasing the error caused by dispersion and by plotting. Platoon or battery salvos may be used in order to assist the sound ranging unit to identify the bursts properly. *ON THE WAY* is given for each round. The adjustment is continued until a suitable bracket has been obtained, at which time the next correction is followed by FIRE FOR EFFECT.

b. Fire for effect. Fire for effect may follow an adjustment on the target or on an auxiliary target, or may be based on a transfer from a center of impact, base point, check point, or other fire of which the flash (sound) unit has determined the location. When conditions permit, the sound ranging unit ranges on a registration, and from data

so determined, corrections are computed for subsequent fire. The firing unit furnishes the coordinates of such points, preferably as determined by survey or photo restitution, otherwise as determined by replot of adjusted data. Surveillance should be executed on all missions in order to obtain maximum effect. The method of fire and time at which fire will commence are given prior to fire for effect, and a report is made on completion of fire. With a sound ranging unit, a battery salvo for surveillance may be requested after fire for effect, since sound records of many sounds close together may not be readable.

165. ILLUSTRATIVE EXAMPLE. An enemy battery has been located by the flash ranging platoon of Battery A and is reported to the battalion command post as follows:

FLASH REPORT, COORDINATES 96.82-79.43, ALTITUDE 315 YARDS, ENEMY BATTERY, THREE PLOTS, ACCURACY 50 YARDS, TIME OBSERVED 0900, WILL ADJUST.

The observation battalion evaluates this report and reports to corps artillery fire-direction center:

FLASH REPORT, COORDINATES 96.82-79.43, ALTITUDE 315 YARDS, ENEMY BATTERY LOCATED BY ABLE FLASH, ACCURACY 50 YARDS, TIME OBSERVED 0900, WILL ADJUST.

Corps artillery fire-direction center directs the 170th Field Artillery Battalion to fire the mission and notifies the observation battalion accordingly. A concentration number is assigned, the target location is given, and surprise fire is specified, as well as the number of rounds to be fired and the channel of communication to be used.

The firing battalion decides to obtain corrections from a 6-round center of impact registration. Direct communication is then established between the flash ranging central and the fire-direction center of the firing unit.

The observation battalion notifies the flash platoon of Battery A to stand by to register the 170th Field Artillery Battalion, and furnishes the coordinates of the center of impact. The observers are oriented on the center of impact.

FRC to FDC	FDC to FRC	Remarks
(1) FIRE MISSION, COORDINATES 96.8-80.0, ALTITUDE 300 YARDS, CENTER OF IMPACT REGISTRATION, 6 ROUNDS AT 30-SECOND INTERVAL, AT MY COMMAND, REPORT TIME OF FLIGHT.	(2) *TIME OF FLIGHT 25 SECONDS; BATTERY IS READY.*	
(3) FIRE.	(4) *ON THE WAY.*	Flash plotting team plots the CI and reports the coordinates and altitude to the FDC. The FDC determines corrections from this data.
(5) FIRE MISSION, CONCENTRATION NO. 90, FIRE FOR EFFECT.	(6) *BATTALION FIRING FOR EFFECT . . . ROUNDS COMPLETE, ALL BATTERIES.*	
(7) MISSION ACCOMPLISHED, FIRE EFFECTIVE.		

* * * * * * *

Paragraphs 166 to 169, inclusive, are not used.

Figures 40 to 47, inclusive, are not used.

Appendix VII and Appendix XI (as added by C1) are rescinded.

[AG 300.7 (25 Jan 47)]

BY ORDER OF THE SECRETARY OF WAR:

DWIGHT D. EISENHOWER
Chief of Staff

OFFICIAL:

EDWARD F. WITSELL
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The Adjutant General

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For explanation of distribution formula, see FM 21–6.